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Anglesea Borefield Ecological Monitoring and Assessment Program 2022



Prepared for: Barwon Water

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Cover photo: Male southern pygmy perch showing breeding colours, captured from Salt Creek during the 2022 fish surveys – Bryce Halliday

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Summary

Introduction

Barwon Water is permitted to extract groundwater from the Anglesea Borefield, under the Bulk Entitlement (Anglesea Groundwater) 2009 (BE) to supplement the water supply to Geelong and surrounding areas when required (Victorian Government 2009). The BE requires data to be collected to monitor the impacts of water drawdown under a Monitoring and Assessment Program (MAP) established in 2009.

Per the updated MAP (revised in 2014) (Victorian Government 2014), Ecology Australia was commissioned to undertake both the aquatic and terrestrial ecological monitoring in 2022. The 2022 aquatic ecological monitoring included the annual macroinvertebrate survey of three sites and fish survey at two sites. The terrestrial monitoring, which is typically biennial and last conducted in 2021, was required again in 2022, as the borefield was operated in 2022, triggering the requirement for the terrestrial monitoring. Ecology Australia has undertaken terrestrial monitoring (vegetation and frogs) since 2009 and aquatic monitoring since 2017.

Methods

Vegetation monitoring was undertaken along 6 permanent transects in the Anglesea Swamp and 4 permanent transects in the Anglesea Estuary. The data collected included:

- Plant species lists
- Ecological Vegetation Class (EVC)
- Plant Functional Group
- Bare ground cover
- Water depth (in the swamp only).

Frog survey data was collected at 8 sites in the Anglesea Swamp and 4 sites in the Anglesea Estuary and included:

- Species richness
- Abundance
- Water quality
- Habitat attributes.

Aquatic monitoring consisted of the one-in-three-year spring macroinvertebrate surveys undertaken at 11 sites as well as targeted surveys for southern pygmy perch and Otway bush yabby at 2 sites. Fish and macroinvertebrate monitoring included:

- Taxonomic diversity (macroinvertebrates)
- Abundance
- Biometrics (fish and crayfish)
- Water quality
- Habitat attributes.

Findings

Vegetation

The number of plant species present in the wetland communities remain largely unchanged within the Anglesea Swamp and Estuary. Overall, frequency of the aquatic plant functional group has decreased across both the Anglesea Swamp and Anglesea Estuary since monitoring commenced, however has remained stable at this lower frequency since 2019. The average frequency of the amphibious functional groups has remained relatively consistent across the Anglesea Swamp and Anglesea Estuary. In the Anglesea Swamp, the dry functional group has remained the least frequent functional group in the swamp and continues to display a slightly decreasing trend across all monitoring years. In the Anglesea Estuary, the dry functional group makes up a higher proportion of all functional groups and has remained relatively consistent across all monitoring years.

Standing water was recorded at all sites in the Swamp. The number of sites containing algal mats has increased to 5 sites compared to 3 sites in 2021. No algae was detected across the Estuary sites in 2022.

Frogs

One or more frog species were recorded within 100 m from 7 of 8 sites within the Anglesea Swamp, with frogs heard calling from more than 100 m away at all 8 sites in 2022. Southern brown tree frog, common froglet and southern bullfrog were all recorded within the Anglesea Swamp. Frogs were only recorded at one of the Anglesea Estuary sites in 2022. Only southern brown tree frogs were recorded within 100 m of LAR1 at the Anglesea Estuary. All records in 2021 were from calling frogs with none visually sighted. Results of the 2022 frog surveys show that the number of frogs heard calling at the estuarine sites are as low as that recorded in 2016 and 2019. Conversely, the Anglesea Swamp sites show an increase in frog numbers compared to 2020 and 2021. As such, both sites showed different responses by different species each year. The high rainfall recorded in 2022 resulted in different responses by frogs within both the Anglesea Swamp and the Anglesea Estuary environment, with the Anglesea Swamp having an increase in frog species while the Anglesea Estuary having a reduction in frog species.

Southern pygmy perch & Otway bush yabby

Southern pygmy perch were again only detected from one of the 2 monitoring sites, the Salt Creek site, which has been a consistent result for the past 5 years. Recruitment was again not detected at the Salt Creek site, however fish appeared in breeding condition (breeding colours displayed and ripe fish present). This year's sampling (2022) was the fifth consecutive year that southern pygmy perch were not recorded in the Breakfast Creek tributary. Based on this result, we suggest that this population may now be locally extirpated. It would be advisable to determine if there is a source population elsewhere in the Breakfast Creek catchment as a possible source of recolonisation into the Breakfast Creek tributary.

Otway bush yabby was detected at 2 sites in 2022 at the Breakfast Creek tributary and Salt Creek site. All Otway bush yabby collected in 2022 from both methods were recorded (measured, weighed, counted as appropriate), adding further knowledge and data for this threatened species. Otway bush yabby have been continually detected at the Breakfast Creek tributary and Salt Creek sites since 2017 (Ecology Australia 2018–2022). Otway bush yabby abundances were higher in 2022 compared with the previous year, however inconsistent methodology for this species since detection have made it difficult

to accurately plot the trajectory of this species through time. A significant number of small, young-of-year/juvenile, individuals were detected in 2022, indicating this species is continuing to recruit successfully at the sites where it is present.

Macroinvertebrates

The macroinvertebrate monitoring results from 2022 were relatively consistent with the previous three years (Ecology Australia 2020–22). A slight improvement was evident in the present year. The overall trend for the macroinvertebrate assemblage for the study area has been decline since at least 2014. New environmental objectives, Environment Reference Standard (ERS) (Victorian Government Gazette, 2021), were used for comparison with the macroinvertebrate assemblage. Attainment of ERS objectives was low with SIGNAL2 (creek sites) and VLAKES (wetland site) being the only categories meeting relevant objectives. Low pH conditions within the more depauperate sites were the likely driver of the poor macroinvertebrate results.

1 Introduction

Barwon Water is permitted to extract groundwater from the Anglesea Borefield, under the Bulk Entitlement (Anglesea Groundwater) 2009 (BE), to supplement the water supply to Geelong and surrounding areas when required (Victorian Government 2009). Groundwater pumping under the BE is permitted as long as it does not adversely affect environmental values and groundwater-dependent ecosystems in the Jan Juc Groundwater Management Area.

The BE requires data to be collected to monitor the impacts of water drawdown. At the commencement of the BE, a Monitoring and Assessment Program (MAP) was developed. The MAP has been revised and updated once, in September 2014 under the Bulk Entitlement (Anglesea Groundwater) 2014 (henceforth to be referred to as the 'BE' succeeding the previous version; Victorian Government 2014). The MAP includes groundwater and surface water monitoring, acid sulphate investigations, land-level surveying and aquatic and terrestrial ecological monitoring (Victorian Government 2014).

Ecology Australia has undertaken the terrestrial (vegetation and frogs) monitoring component of the MAP since 2009 and the aquatic component (fish and macroinvertebrates) since 2017 (Ecology Australia 2009–2022).

The current MAP requires aquatic ecological monitoring to be undertaken annually (with an increased number of sites every 3 years), and terrestrial ecological monitoring to be undertaken biennially in the absence of groundwater pumping, and annually during periods of groundwater extraction (Victorian Government 2014). Barwon Water operated the borefield in 2022 between January and October extracting a total volume of 1787.96 ML (Barwon Water 2023). As borefield extraction occurred during 2022 (i.e. during this present reporting period) the MAP requirement for terrestrial ecological monitoring was triggered.

The 2022 ecological monitoring includes the Aquatic Ecology and Terrestrial Ecology components as detailed below.

1.1 Aquatic ecology

The Aquatic Ecological monitoring component included the annual spring monitoring of macroinvertebrates at 3 sites:

- Breakfast Creek tributary 1 (BCT1)
- Salt Creek (SC1)
- Lower Anglesea River wetland 2/3 (W2/3).

Additionally, this component included spring sampling of southern pygmy perch *Nannoperca australis* and Otway bush yabby *Geocherax tasmanicus* at 2 sites:

- Breakfast Creek tributary (BCT1)
- Salt Creek (SC1).

1.2 Terrestrial ecology

The Terrestrial Ecological monitoring component included spring monitoring of vegetation along established transects at 6 sites and frog monitoring at 8 sites in the Anglesea Swamp (Figure 1):

- AS1_2014 (vegetation and frog monitoring)
- AS2 (vegetation and frog monitoring)
- AS3 (vegetation and frog monitoring)
- AS4 (vegetation and frog monitoring)
- AS5 (frog monitoring only)
- AS6 (frog monitoring only)
- ASP7_2014 (vegetation and frog monitoring)
- AGP2_2014 (vegetation and frog monitoring).

Additionally, spring monitoring of vegetation was undertaken at established transects at 4 sites and frog monitoring was undertaken at the same sites in the Anglesea Estuary:

- LAR1
- LAR2
- LAR3
- LAR4.

Vegetation data collection included floristic species lists, Ecological Vegetation Classes (EVCs), plant Functional Groups, and other structural and physical attributes (water depth, bare ground and algal mats).

The frog monitoring data collection included species richness, abundance, water quality, and habitat attributes.

This report presents the monitoring methods and results, along with a discussion including a comparison of the 2022 data with annual data collected since the MAP review and update in 2014.

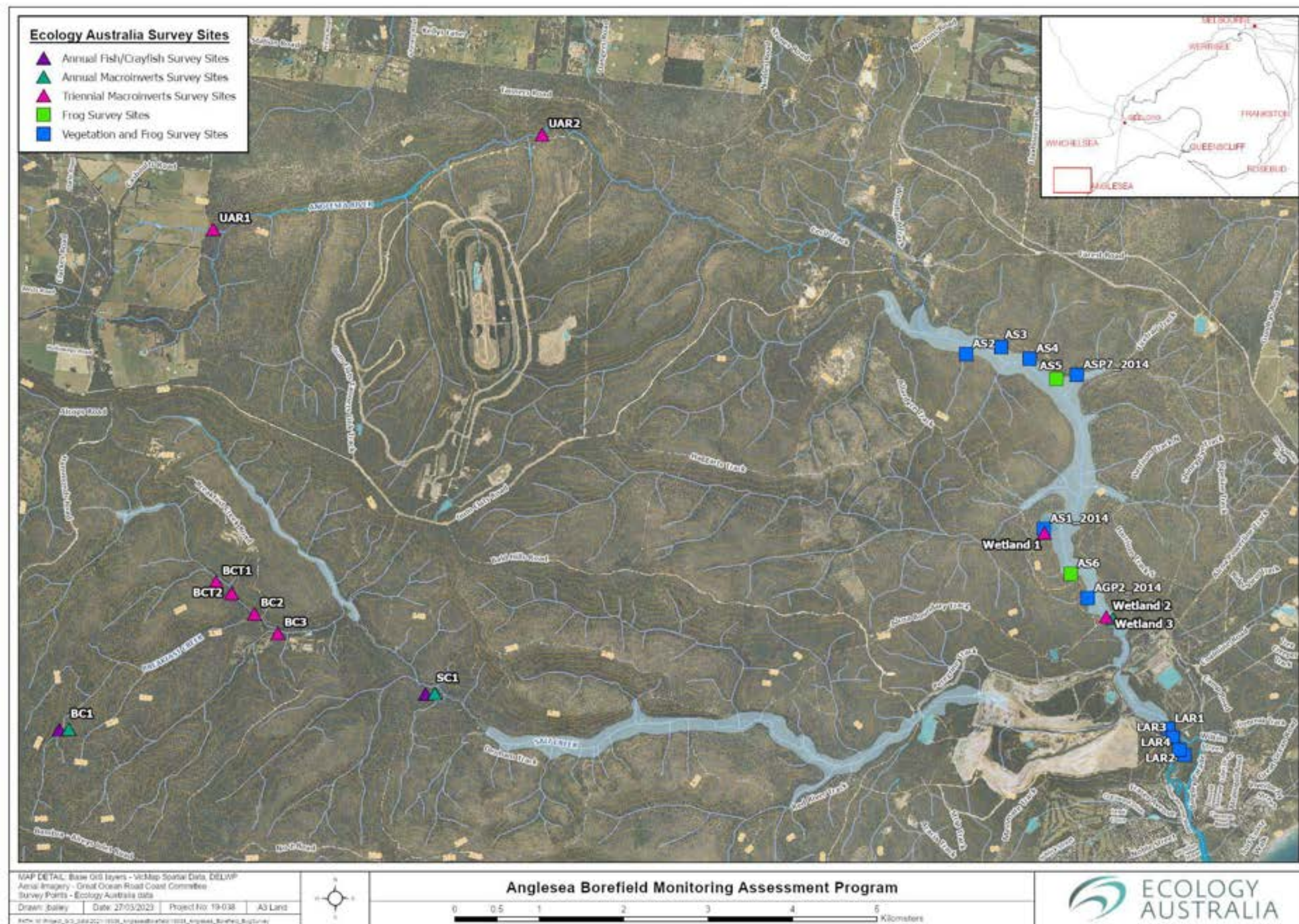


Figure 1 Anglesea Borefield ecological Monitoring and Assessment Program survey sites, 2022.

2 Methods

2.1 Vegetation

Vegetation monitoring was undertaken during the first and last week of November 2022 at the following sites in the Anglesea Swamp: AS1_2014, AS2, AS3, AS4, ASP7_2014 and, AGP2_2014; and at the following sites in the Anglesea Estuary: LAR1, LAR2, LAR3, and LAR4.

2.1.1 Data collection

One established 100 m transect was surveyed at each site. Along each transect, 1 m² quadrats were located every second metre along the left-hand side of the transect looking start to end, with the first quadrat placed at 1–2 m, the second placed at 3–4 m and so on. Therefore, 50 quadrats were established along each transect in the Anglesea swamp, 15 quadrats along LAR2, LAR3 and LAR4 transects and 7 quadrats along LAR1 in the estuary sites. Field staff walked on the right-hand side of the transect to avoid trampling vegetation within quadrats.

Survey methods collect the presence/absence of flora species within quadrats located along transects to produce a frequency score for each species. Each species that was alive and rooted in or overhanging each quadrat was recorded.

Additionally at each quadrat, EVCs following the Department of Environment, Land, Water and Planning (DELWP) benchmarks (DELWP 2022a) were recorded, as well as other attributes including water depth (in the swamp only) and percentage cover of bare ground (representing potential change at a site due to potential recruitment) rounded to the nearest 5% and presence of algal mats. Photo points were taken at each site and located at 0 m, 25 m, 50 m, and 75 m along each transect in the swamp and the start of each transect in the estuary. Photos were taken looking toward the end of the transect.

Plant functional groups

Plant species recorded in surveys across the Anglesea Swamp and Anglesea Estuary were classified into functional groups (FGs) (Table 1). Functional groups were based on the ecology (known or likely water requirements) of plant species, modified from Cassanova (2011) and Doeg *et.al.* (2012), as detailed in Ecology Australia (2013b). Functional group T (instead of Tdr or Tda) and A (instead of Ate, Atl, Atw or Arp) were assigned where species were identified to genus or family level only.

2.1.2 Data analysis

Species composition

Species richness was presented in a table form displaying total number of native species and number of plants per broad functional group. Additionally, species richness was presented in a bar chart form for each site across each monitoring period.

Plant functional groups

Plant functional groups were used to assess the changes in ground water dependant vegetation across the swamp and estuary.

For both the Anglesea Swamp and Anglesea Estuary, charts were produced to display the proportion of functional group (Atw, Ate, Atl, Arp, Se, T, Tdr and Tda) abundance data across all sites for each monitoring period along with average rainfall.

At an individual site level, the average percentage frequency of broad functional groups was presented in a bar chart form for all monitoring years. The top 3 dominant species for each site were presented as a line chart as the percentage frequency across all monitoring years. For any given year, the dominant 3 species were displayed, therefore sites with fluctuating dominant species across the years may display more than 3 species.

Considerable ambiguity in the taxonomy exists when distinguishing between manuka *Leptospermum scorparium* and the prickly tea-tree *Leptospermum continentale* (Tdr). Therefore, records of prickly tea-tree and manuka were grouped together in this years' analysis as tea-tree *Leptospermum spp.* and assigned the summary functional group of T (Terrestrial). Similarly, within the water-ribbons *Cycnogeton* species, this group is taxonomically unresolved which has led to variation in the number of species recorded over the years (either *Cycnogeton procerum* or *Cycnogeton alcockiae* or both). Until the taxonomy of this species is finalised, all *Cycnogeton* records will be lumped under *Cycnogeton procerum* spp. aff for data analysis.

Algal mats

The presence of algal mats was presented in a bar chart form as the percentage frequency of algal mat at each site across all monitoring years.

Table 1 Anglesea Borefield, ecological Monitoring and Assessment Program, Plant Functional Groups (modified from Cassanova 2011 and Doeg *et.al.* 2012).

FG	Definition	Example species
Dry		
Tdr	<i>Terrestrial dry</i> . This species group does not require flooding and will persist in damper parts of the landscape because of localised high rainfall. Species in this group can invade or persist in riparian zones and the edges of wetlands but are essentially terrestrial.	Messmate, Brown Stringybark, Prickly Moses, Silver Banksia
Tda	<i>Terrestrial damp</i> . These species germinate and establish on saturated or damp ground but cannot tolerate flooding in the vegetative state. They require the soil profile to remain damp for at least several months.	Swamp Gum, Variable Sword-sedge, Manuka, Slender Bog-sedge
Amphibious		
Ati	<i>Amphibious fluctuation tolerator - low-growing</i> . This species group can germinate either on saturated soil or under water and grow submerged, as long as they are exposed to air by the time they start to flower and set seed. They require or tolerate shallow flooding for approximately 3 months.	Austral Brookline, Swamp Club-sedge, Spotted Knotweed
Ate	<i>Amphibious fluctuation tolerator - emergent</i> . This species group consists of emergent monocots and dicots that survive in saturated soil or shallow water but require most of their photosynthetic parts to remain above the water (emergent). They tolerate fluctuations in the depth of water, as well as water presence. They need water or soil moisture to be present for 8–12 months of the year.	Tall Sedge, Red Fruit Saw-sedge, Pouched Coral-fern, Scrambling Coral-fern
Atw	<i>Amphibious fluctuation tolerator- woody</i> . This species group consists of woody perennial species that may hold their fruits (and seeds) in the canopy and require water to be present in the root zone all year round but will germinate in shallow water or on a drying substrate.	Woolly Tea-tree, Scented Paperbark
Arp	<i>Amphibious fluctuation responder - plastic</i> . This species group occupies a similar zone to the ATI group, except that they have a morphological response to water level changes such as rapid shoot elongation or a change in leaf form. They can persist on damp and drying soil because of their morphological flexibility but can flower even if the site does not dry out. They occupy a slightly deeper/wet-for-longer site than the ATI group.	Creeping Cotula, Monkey Flower, River Buttercup
Aquatic		
Se	<i>Perennial-emergent</i> . This category refers to monocotyledonous species that require permanent water in the root zone but remain emergent. They occur where water levels do not fluctuate or fluctuate with a relatively little drawdown in the dry part of the year.	Cumbungi, Sea Rush, Southern Water-ribbons

2.2 Frogs

A survey team of 2 zoologists undertook 2 repeat surveys for frogs at 12 sites on 2–3/11/2022 and 28–29/11/2022 (Figure 1):

- AS1_2014, AS2, AS3, AS4, AS5, AS6, ASP7_2014 and AGP2_2014 in the Anglesea Swamp
- LAR1, LAR2, LAR3 and LAR4 in the Anglesea Estuary.

The survey sites comprise the 10 sites required by the MAP, as well as 2 additional sites (AS5 and AS6), which are surveyed if very low frog activity is observed at the Anglesea Swamp. Unlike the approach used for surveys conducted in 2021, where a local community group provided information on frog diversity from the greater Anglesea area, the surveys undertaken by Ecology Australia in the 2022 season were the only data on frog diversity included in the current study.

2.2.1 Habitat assessment and water quality

To supplement the habitat data collected as part of vegetation monitoring, the following frog habitat variables were recorded:

- Wetland permanence (i.e. ephemeral, semi-permanent or permanent)
- Water quality parameters:
 - Temperature (° C)
 - pH
 - Electrical Conductivity (EC) (mS/cm)
 - Dissolved Oxygen (DO) (mg/L)
 - Turbidity (NTU)
- A general habitat description, including cover of fringing, emergent, submergent and floating vegetation.

Photos were also taken showing representative frog habitats at each survey site.

2.2.2 Frog surveys

A pair of zoologists used both diurnal and nocturnal visual and auditory surveys to detect frogs at the survey sites. Nocturnal surveys also included call playback and spotlighting. Weather conditions at the time of the survey were recorded using a Kestrel weather meter. In 2022, all frog survey events were completed during suitable weather in spring.

Visual surveys

Visual and aural surveys were undertaken at each site during the diurnal habitat assessment and at the beginning of each nocturnal survey. Surveys comprised 2 zoologists listening for approximately 5 minutes for the distinctive calls of male frogs. The species heard, and an estimation of the number of frogs calling for each species was recorded. In addition, zoologists looked for frogs at each site, by traversing the sites and scanning vegetation and the water surface for the presence of frogs. Visual nocturnal surveys were aided by the use of head-torches and/or hand-held spotlights, to look for the distinctive eye-shine of frogs.

Nocturnal call playback

Call playback was used following the nocturnal aural survey to elicit calling behaviour by male frogs that were not calling independently onsite. This approach uses the broadcast of pre-recorded calls of each species through a speaker, followed by a period of quiet listening. Frog calls broadcast during call playback, based on previous records included:

- southern brown tree frog *Litoria ewingii*
- southern bullfrog *Limnodynastes dumerilii*
- spotted marsh frog *Limnodynastes tasmaniensis*
- striped marsh frog *Limnodynastes peronii*
- common spadefoot toad *Neobatrachus sudellae*
- Victorian smooth froglet *Geocrinia Victoriana*
- common froglet *Crinia signifera*.

Call response data were used to estimate frog species richness and abundance within each site across the Anglesea catchment and estuary.

2.3 Aquatic ecology

2.3.1 Macroinvertebrate surveys

Macroinvertebrate surveys were undertaken at 3 sites between 22–23 November 2022. As per the established methods for this program (GHD 2016), triplicate edge samples were collected at each site where sufficient surface water was present, following the methods outlined in the Victorian Rapid Bioassessment (RBA) Methodology for Rivers and Streams (EPA 2021). A 250 µm mesh net with a 30 cm x 30 cm opening was used to collect each sample. Edge ('sweep') samples were collected from sites with little to no flow. The sampling objective of the RBA method is to subsample all types of microhabitats present, which can include overhanging vegetation, coarse woody debris, backwaters, bare edges, leaf packs and macrophytes. Each sample was collected from 10 m of habitat, which was not necessarily contiguous. The water column and microhabitats present were agitated to dislodge macroinvertebrates, suspend them within the water column and collect them within the net.

Samples were live-sorted ('picked') following the standard RBA procedures and preserved in 70% ethanol. In summary, the procedures entail:

- Picking for 30 minutes from a white tray, aiming to collect 200 animals from as many different taxa as possible
- If less than 200 animals are collected within 30 minutes, then picking continues for an additional 10 minutes
- If 200 animals are collected within 40 minutes and no new taxa are detected, then picking ceases; otherwise picking continues for an additional 10 minutes. This continues until a maximum of 60 minutes of picking has been completed
- Picking a maximum of approximately 30 of each taxa, except for groups that typically require microscopic examination to identify to the taxonomic resolution of family (e.g. Amphipoda) or taxa which are to be identified to a lower taxonomic resolution than family (e.g.

Chironomidae to sub-family, and Odonata, Ephemeroptera, Plecoptera and Trichoptera to genus).

At each site, RBA field sampling and habitat assessment sheets were completed, including *in situ* water quality measurements using a calibrated Horiba U-52 water quality meter.

Since the detection of Otway bush yabby *Geocherax tasmanicus* in 2017, this species has been monitored concurrently with fish and macroinvertebrates (Ecology Australia 2018–2022). During the 2022 macroinvertebrate surveys all Otway bush yabby (and southern pygmy perch) captured in the sweep nets were biometrically recorded per sweep sample as per section: 2.3.4 increasing the available data for these species.

2.3.2 Macroinvertebrate identification

Macroinvertebrates were identified and enumerated with a stereo microscope using keys outlined in MDFRC (2013), which provides an update on those outlined in Hawking (2000). The majority of taxa were identified to family level, with the following exceptions as per the RBA protocols (EPA 2003):

- Chironomidae are identified to sub-family
- Oligochaeta and acarina are not identified below these taxonomic levels
- Adult and larval beetles are differentiated
- Terrestrial, semi-terrestrial and microcrustacean taxa were excluded
- Specimens of the orders Ephemeroptera, Plecoptera, Trichoptera and Odonata were identified to genus level, as per GHD (2016).

2.3.3 Macroinvertebrate data analyses

Macroinvertebrate data were analysed both at individual sample and site scale (using the combined data from 3 samples). Where available, the results were compared against indices objectives outlined in the Environment Reference Standard (ERS) (Victorian Government Gazette, 2021) for rivers and streams in the 'Central Foothills and Coastal Plains' geographic region and for 'shallow inland with outflow' wetlands. Combined data is used for comparisons with previous years to indicate the overall trend of a site and when compared with ERS objectives is indicative only and the results at a sample level should be used when assessing an individual site.

The following indices were used to analyse macroinvertebrate data:

- Number of macroinvertebrate families — total number of taxa based on taxonomic resolution levels described above.
- SIGNAL2— average SIGNAL score for taxa collected in each sample, based on methods of Chessman (2003).
- VLAKES (new index used for ERS objectives for macroinvertebrates samples taken from wetlands) – average VLAKES score for taxa collected in each sample, based on methods of EPA (2010).

The following indices have been included in the analysis to show the number of more sensitive taxa and for ease of comparison with past reports, but were not compared to an objective as they are not included as objectives for edge samples within the ERS:

- EPT — number of genera from the orders of Ephemeroptera, Plecoptera and Trichoptera (EPT). These taxa are typically considered more sensitive to pollution and disturbance and hence the index is an indicator of ecosystem health and
- EPTO — number of genera from the orders of Ephemeroptera, Plecoptera, Trichoptera and Odonata (EPTO). This modified version of the EPT index is used for waterways in 'Mediterranean climate' regions, and aid in interpreting the health of lentic (still water) systems, where the numbers of Plecoptera are diminished, while Odonata, which are also relatively sensitive to pollutants and disturbance, are more abundant and diverse (Pinto et al. 2004).

2.3.4 Fish surveys

Surveys targeting southern pygmy perch *Nannoperca australis* and Otway bush yabby *Geocharax tasmanicus* were undertaken at 2 sites: BCT1 and SC1 on 17 and 18 November 2021, respectively. For consistency with previous surveys, the BCT1 fish site was again relocated downstream at the V-notch gauging station.

Ten bait traps (stretched mesh size of 2 mm and funnel entrances of 40 mm diameter) with 100 mm long yellow glow sticks placed inside to serve as an attractant, were set in the afternoon and retrieved the following morning at both sites. This is consistent with the monitoring approach used in recent years (Ecology Australia 2018–2022).

All captures of southern pygmy perch and Otway bush yabby were recorded separately per gear type and replicate. The first 50 southern pygmy perch and Otway bush yabby captured at each site were measured (total length) to the nearest mm and weighed to the nearest 0.1 g (where their weight exceeded 1.0 g). All remaining southern pygmy perch and Otway bush yabby were counted. All southern pygmy perch and Otway bush yabby were returned to the point of capture.

2.4 Conservation status

Threatened species of state and/or national conservation significance were determined by reference to listings under the Victorian *Flora and Fauna Guarantee Act 1988* (FFG Act) and the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

2.5 Nomenclature and taxonomy

All scientific names, common names and systematic orders of flora and fauna species follow the Victorian Biodiversity Atlas (DELWP 2022b), with common names referring to fauna within the text of the report.

Where an asterisk (*) precedes a plant name it is used to signify non-indigenous taxa, those species which have been introduced to Victoria or Australia. A hash (#) is used to denote Victorian plant species that are not indigenous to the region or local area.

3 Results

Vegetation and frog monitoring were undertaken at the same sites (with two additional sites for frogs). The findings for each of the sites is presented below followed by site summaries in Section 3.2.4.

The aquatic ecology monitoring was carried out at sites in different locations to the terrestrial monitoring sites and as such the site summaries are presented separately in Sections 4.3.

3.1 Vegetation

Site summaries displaying the results of vegetation monitoring are provided in Figure 8, Figure 9, Figure 10, Figure 11, Figure 12, Figure 13, Figure 16, Figure 17, Figure 18 and Figure 19.

3.1.1 Floristic composition

A total of 30 vascular indigenous plant species were recorded across all sites in the Anglesea Swamp, while no exotic species were recorded (Appendix 1). In the Anglesea Estuary, 17 plant species were indigenous (81%), 2 were exotic (9.5%) and 2 were native Victorian species not indigenous to the study area (9.5%) (Appendix 2). Species richness in the Anglesea Swamp increased from 29 to 30 species between 2021 and 2022, while in the Anglesea Estuary sites, total species richness decreased by 6 species from 27 to 21 and native species remained stable at 17 species between 2021 and 2022.

Changes in species richness were variable across sites. Species richness decreased at 4 of the 6 Anglesea Swamp sites and increased at 2 sites compared to the 2021 monitoring season (Figure 2). Across the Anglesea Estuary, species richness remained stable at one site but decreased at 3 sites compared to 2021 (Figure 3). Furthermore, native species richness varied across sites, ranging from 7 to 15 in the swamp and 4 to 11 in the estuary (Table 2).

Table 2 Number of native plant species and associated functional groups recorded across Anglesea Borefield ecological Monitoring and Assessment Program sites.

Transect/Site	Total number of native plant species	Number of plant species in a dry FG	Number of Amphibious FG plants	Number of plant species in an Aquatic FG
Anglesea Swamp				
AS2	15	10	2	3
AS3	12	3	8	1
AS4	13	2	9	2
ASP7_2014	13	2	9	2
AS1_2014	10	2	6	2
AGP2_2014	7	1	4	2
Anglesea Estuary				
LAR1	9	3	3	3
LAR2	11	6	3	2
LAR3	10	5	3	2
LAR4	4	0	2	2

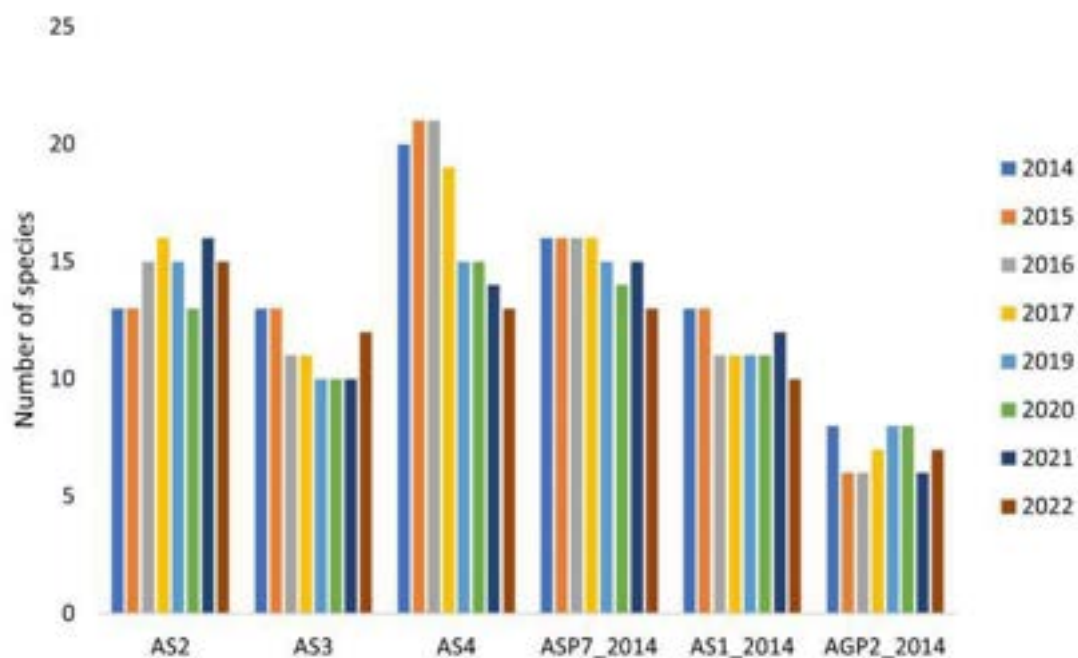


Figure 2 Native species richness at each survey site in the Anglesea Swamp (AS2, AS3, AS4, ASP7_2014, AS1_2014 and AGP2_2014) for each season which required monitoring.

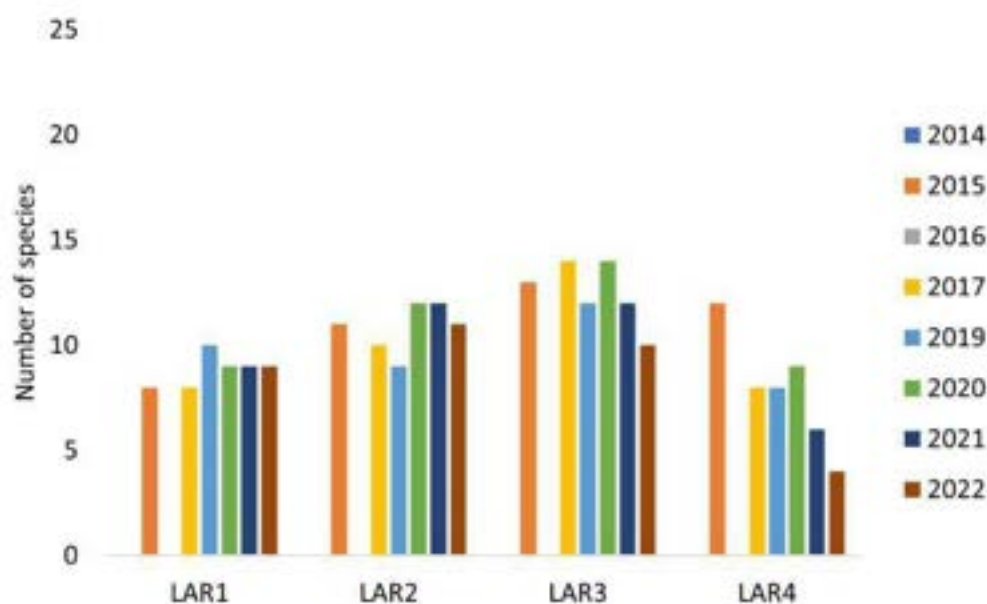


Figure 3 Native species richness at each survey site in the Anglesea Estuary (LAR1, LAR2, LAR3 and LAR4) for each season which required monitoring.

Anglesea Swamp

In the Anglesea Swamp, 7 FGs were represented (T, Tdr, Tda, Se, Atw, Atl and Ate), while no species from Arp functional group were recorded (Figure 4). Average proportions of functional groups remained relatively stable compared to 2021, however Atl species increased from .1% to .78% while Tda increased from .3% to 1.23%. Overall, Ate, Atl and Atw species have exhibited a longer-term trend of declining as a proportion of the plant community since 2019. However, the proportion of aquatic species (Se) has steadily increased over this time period. The 2021 rainfall data from Aireys Inlet shows an average annual rainfall of 631 mm from 1994 to 2021 (BOM 2022) and the 2021 rainfall was above average 726 mm. Aireys Inlet data was incomplete for 2022 and therefore data from the nearest weather station at Wendsleydale was used for those months (June, July and August).

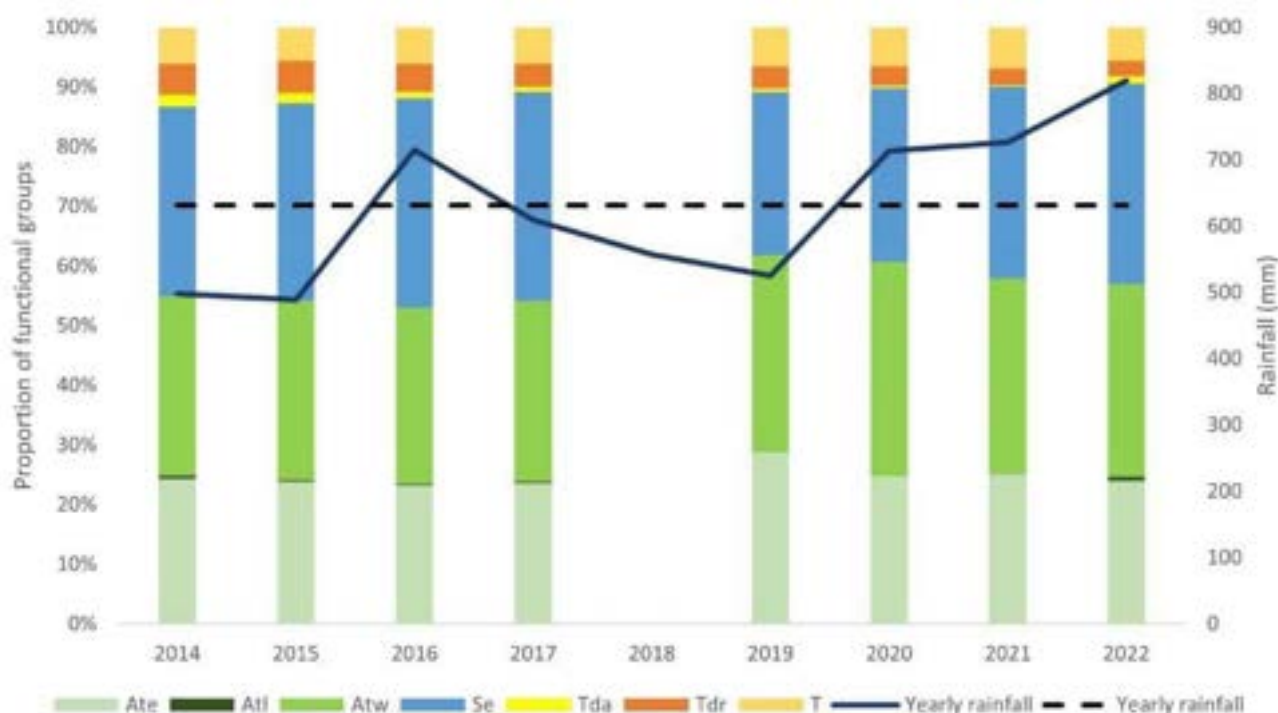


Figure 4 Average percentage frequency of broad functional groups (Amphibious FG, Aquatic FG and Dry FG) (left y-axis) and yearly and mean annual rainfall (right y-axis) across all sites in the Anglesea Swamp for each monitoring period. Swamp sites were not monitored in 2018 due to no water extraction to triggering monitoring.

Anglesea Estuary

Plants from 7 FGs were recorded in the Anglesea Estuary (T, Tda, Tdr, Se, Ate, Atl, Arp), while no species from the Atw FGs were recorded (Figure 5). Average proportion of species in the functional group Arp declined slightly in 2022 (24.1%) from 2021 (22.4), continuing a longer-term trend dating back to 2019. Aquatic (Se) species increased slightly from 27.7% in 2021 to 31.3% in 2022, while other functional group proportions remained relatively stable.

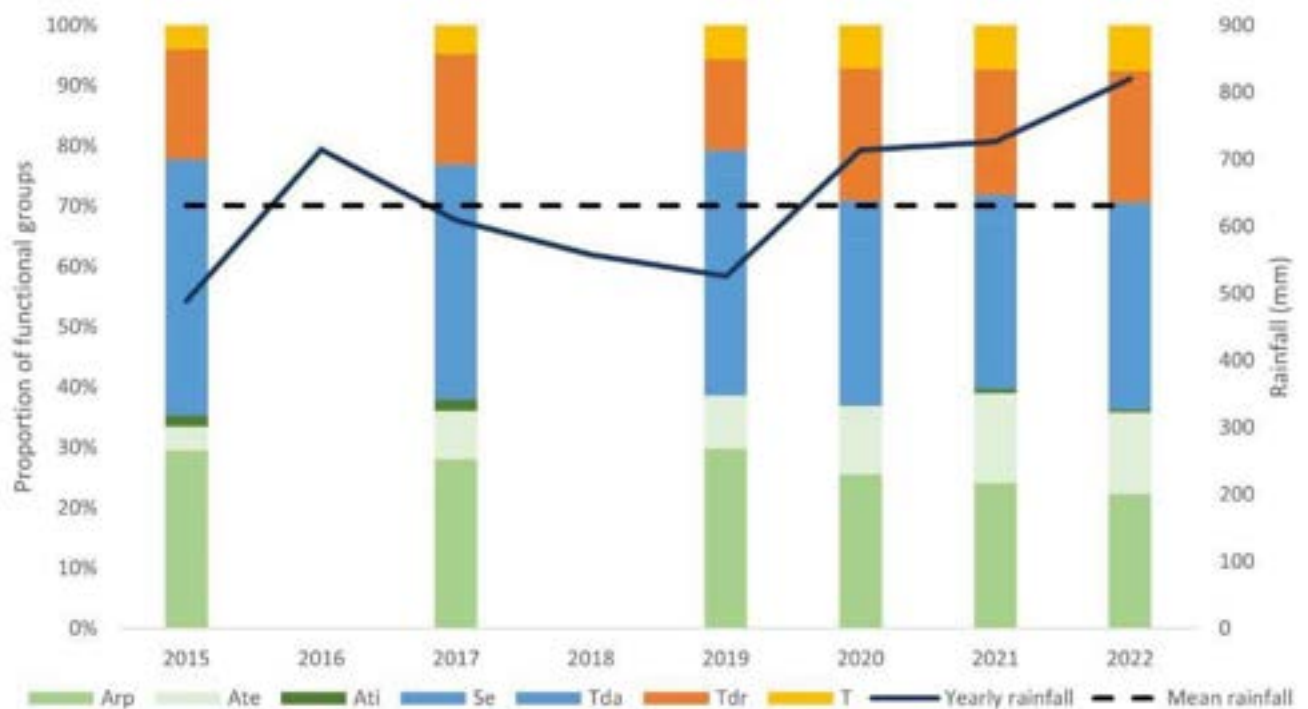


Figure 5 Average percentage frequency of broad functional groups (Amphibious FG, Aquatic FG and Dry FG) (left y-axis) across all sites in the Anglesea Estuary for each monitoring period and yearly and mean annual rainfall (right y-axis). Estuary sites were not monitored in 2016 and 2018 due to no water extraction to triggering monitoring.

Algal mats

Algal mats were present at all sites with the exception of AS3. Algal mat frequency increased greatly at ASP7_2014, where they hadn't previously been recorded since 2019 and even then remained at a very low frequency. Algal mat frequency was stable at AS1_2014, AGP2_2014 and AS4 compared with 2021, while algal mat presence was detected at AS2 for the first time in just one quadrat. Algal mats were not recorded in any of the Anglesea Estuary sites in 2022 (Figure 6).

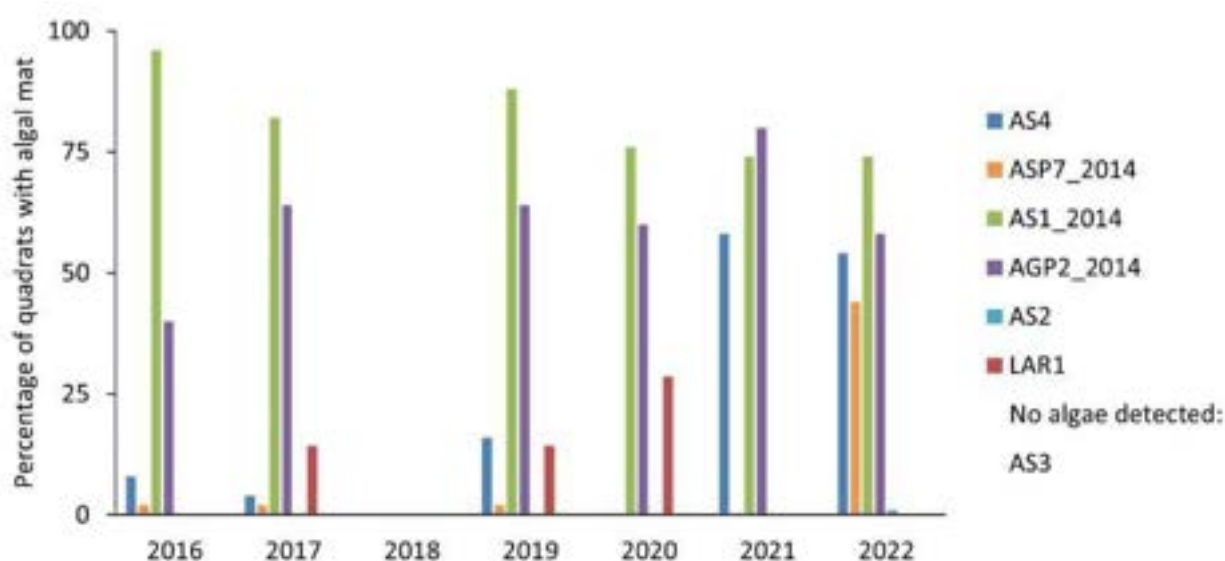


Figure 6 Algae mat records at all sites in the Anglesea Swamp and Anglesea Estuary from first detection in 2016. No monitoring was undertaken in the Anglesea Swamp 2018 or in the Anglesea Estuary in 2016 or 2018 due to no water extraction triggering monitoring.

3.2 Frogs

3.2.1 Survey conditions

The 8 sites at the Anglesea Swamp all contained water over the period that the 2 frog survey events were conducted. The average water depth among all Anglesea Swamp sites at the time of the first survey being approximately 0.35 m, with the average water depth among all study sites having increased to approximately 0.36 m by the time of the second survey. Similarly, the average depth of the estuary sites having increased from 1.63 m to 2.75 m by the time of the second survey event.

The weather conditions recorded during the two nocturnal frog surveys are summarised in Table 3.

Table 3 Weather conditions during nocturnal frog surveys, 2022.

Variable	Survey 1	Survey 2
Temperature (°C)	12.4	14.3
Humidity (%)	88.6	79.4
Cloud cover (0–8)	6.3	2.4
Moon light (0–4)	1.4	1.5
Wind speed (0–3)	0.5	0.5
Rainfall during survey (0–3)	0	0
Rain in past 24 hours (None–heavy)	Low	Low

3.2.2 Frog species richness and abundance

The number of frogs estimated to be calling within 100 m of each of the study sites is provided in Figure 7. Since 2014, the number of frogs detected calling has varied among years, with an obvious peak in frog abundance in 2016 for the swamp sites and in 2020 for the estuary sites. The common froglet was the most abundant frog species at the swamp sites in 2022 and had the highest number of individuals (50) detected since 2014. The number of southern tree frogs detected in 2022 was the highest (13) since the study began in 2014, with the number of southern bullfrogs also increasing to the highest (26) amount since 2016. All other frog species either decreased or did not change in abundance since the 2021 surveys. Total rainfall recorded over the winter and spring period for each year indicates 2 obvious peaks in 2016 and 2022, respectively. These rainfall peaks represent the two La Niña events that have occurred since the commencement of frog monitoring at the Anglesea swamp and estuary in 2014. Finally, the two peaks in frog abundance within the Anglesea swamp appears to be positively related to the two La Niña rainfall (2016, 2022) peaks.

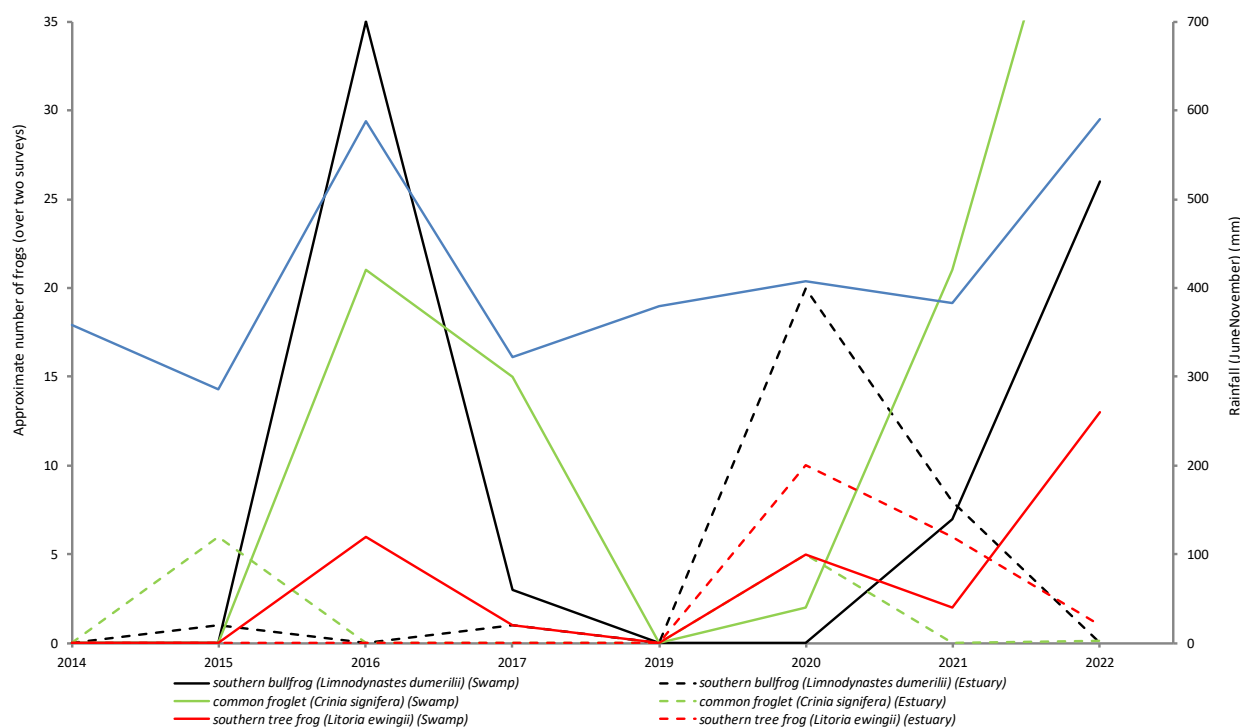


Figure 7 The number of frogs detected calling within 100 m of the survey sites at Anglesea swamp and Anglesea estuary from 2014 to 2022. Included is the total winter and spring rainfall recorded at Aireys Inlet (blue line).

Anglesea Swamp

Frogs were recorded from within 100 m of 7 of the 8 sites within the Anglesea swamp (Table 4), with frogs heard calling from more than 100 m at all Anglesea swamp sites. All the records were from calling individuals as there were no individuals sighted visually. The maximum number of frog species (species

diversity) detected at any one site was 3 species: southern brown tree frog *Litoria ewingii*, common froglet *Crinia signifera* and southern bullfrog (pobblebonk) *Limnodynastes dumerilii*.

Sites AS1_2014, AS2, AS3, AS5 and AGP2_2014 all showed equal maximum species richness with all three frog species recorded being recorded across the 2 survey events. However, with the inclusion of frogs calling from greater than 100 m away were taken into account, both AS4 and ASP7_2014 also had all 3 species present.

Table 4 Frog species detected during nocturnal surveys and estimated abundances at the Anglesea Swamp sites. The number of frogs heard calling more than 100 m from the survey sites are listed in parentheses.

Site	Southern Brown Tree Frog		Common Froglet		Southern Bullfrog (Pobblebonk)		Species richness
	1	2	1	2	1	2	
AS1_2014	0 (0)	2 (0)	11-20 (0)	2 (0)	7 (0)	12 (0)	3
AS2	4 (0)	3 (0)	11-20 (0)	11-20 (0)	5 (0)	11-20 (0)	3
AS3	7 (0)	3 (0)	0 (0)	7 (0)	7 (0)	3 (5)	3
AS4	0 (5-10)	0 (2)	0 (5-10)	0 (3)	0 (3)	0 (11-20)	0
AS5	0 (5-10)	2 (0)	2 (0)	3 (0)	3 (0)	0 (3)	3
AS6	0 (0)	0 (0)	11-20 (0)	11-20 (0)	0 (0)	0 (4)	1
ASP7_2014	0 (2)	0 (5-10)	4 (0)	8 (1)	0 (3)	3 (4)	1
AGP2_2014	2 (0)	0 (0)	7 (0)	0 (0)	4 (0)	0 (3)	3

Anglesea Estuary

Frogs were recorded within 100 m at all Anglesea swamp sites with the exception of AS4 (Table 4). In contrast, relatively few frogs were detected at the Anglesea estuary site, with southern brown tree frog being the only species detected at any of the estuary sites (Table 5). However, while southern brown tree frog was detected at estuary site LAR1 during the first survey, it was detected at distances of greater than 100 m for all other Anglesea estuary (LA2, LA3, LA4) sites. Further, common froglet (LAR4) and southern brown tree frog (LA3 and LA4) was detected at a distance greater than 100 m on survey 2, with southern brown tree frog the most frequently detected frog during the second survey.

Table 5 Frog species detected during nocturnal surveys and estimated abundances at the Anglesea Estuary sites, 2022. The number of frogs heard calling more than 100 m from the survey sites are listed in parentheses.

Site	Southern Brown Tree Frog		Common Froglet		Southern Bullfrog (Pobblebonk)		Species Richness
	1	2	1	2	1	2	
LAR1	1 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1
LAR2	0 (3)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0
LAR3	0 (3)	0 (3)	0 (0)	0 (0)	0 (0)	0 (0)	0
LAR4	0 (3)	0 (3)	0 (0)	0 (1)	0 (0)	0 (0)	0

3.2.3 Habitat assessment and water quality

Anglesea Swamp

The Anglesea Swamp monitoring sites mostly support dense shrub cover of scented paperbark *Melaleuca squarrosa* and prickly teatree *Leptospermum continentale*, which open up into clearings of emergent aquatic vegetation, largely sedges such as zig-zag bog-sedge *Schoenus brevifolius*, square twig-sedge *Machaerina tetragona* and fine twig-sedge *M. arthropophylla*. Swards of dead and live sedges occasionally form thick mats across the site. Fringing vegetation sometimes includes shorter pink swamp-heath *Sprengelia incarnata* or pouched coral-fern *Gleichenia dicarpa*. Where monitoring sites support standing water, common water-ribbons *Cynnogeton procerum* sp. aff. and filamentous algae may be present as submergent and floating vegetation. Some sites also include small patches of bare ground and low cover of woody debris, especially at the interface between emergent and fringing vegetation.

All monitoring sites are considered intermittent except for AS3 (semi-permanent) and AS4 (semi-permanent to permanent). During the 2022 surveys, all sites had sufficient standing water to allow for all water quality parameters to be measured during both the first and second survey. In general, all sites were acidic (pH of 3.18–5.35) and electrical conductivity was low to moderate, ranging from 0.30 to 3.50 ms/cm. Water temperatures were relatively high, with all but 3 measurements above 13 °C (range: 11.13–20.50°C). Turbidity was more variable across sites, being generally low (range: 0–27 NTU) with the majority of values under 10 NTU. Similarly, dissolved oxygen levels were variable (range: 3.8–9.7 mg/L), with the dissolved oxygen levels slightly lower in the second survey.

Anglesea Estuary

The Anglesea Estuary is relatively deep, with slow-moving water. Apart from filamentous algae, the cover of aquatic vegetation was generally low, particularly the cover of floating and submergent vegetation. Common reed *Phragmites australis* is an emergent species that provides sparse emergent vegetation at most sites. Fringing vegetation occurs at higher levels of cover, dominated by grasses, sedges, rushes and herbs including cast tussock-grass, *Poa poiformis* var. *poiformis*, common blown-grass *Lachnagrostis filiformis*, sea rush *Juncus kraussii* ssp. *australiensis* and shiny swamp-mat *Goodenia radicans*. LAR1 also supports narrow-leaf cumbungi *Typha domingensis* and southern water-ribbons.

Scattered shrubs of hop goodenia *Goodenia ovata*, manuka *Leptospermum scoparium* and stands of swamp gum *Eucalyptus ovata* var. *ovata* were recorded near the water's edge.

All estuary monitoring sites are considered permanent, with stream widths ranging from 2–3 m to approximately 12 m wide, and up to 1–2 m deep. As such, water quality could be measured at all sites, and values were generally consistent between sites within surveys, compared to the measurements taken in the Anglesea swamp. All sites had very low pH (2.73–4.12), and water temperature above 13 °C during the first survey and 15–20 °C during the second survey. Electrical conductivity readings were relatively low during the first survey (3.5–4.0 ms/cm), with similar EC (0.5–6.5 ms/cm) among the 2 surveys. Conductivity remained relatively constant with a mean of 3.47 ms/cm in the first survey, to 3.82 ms/cm in the second survey. Turbidity was low (0–2 NTU) and dissolved oxygen concentrations varied from 6.2 to 9.3 mg/L.

3.2.4 Vegetation and frog site summaries

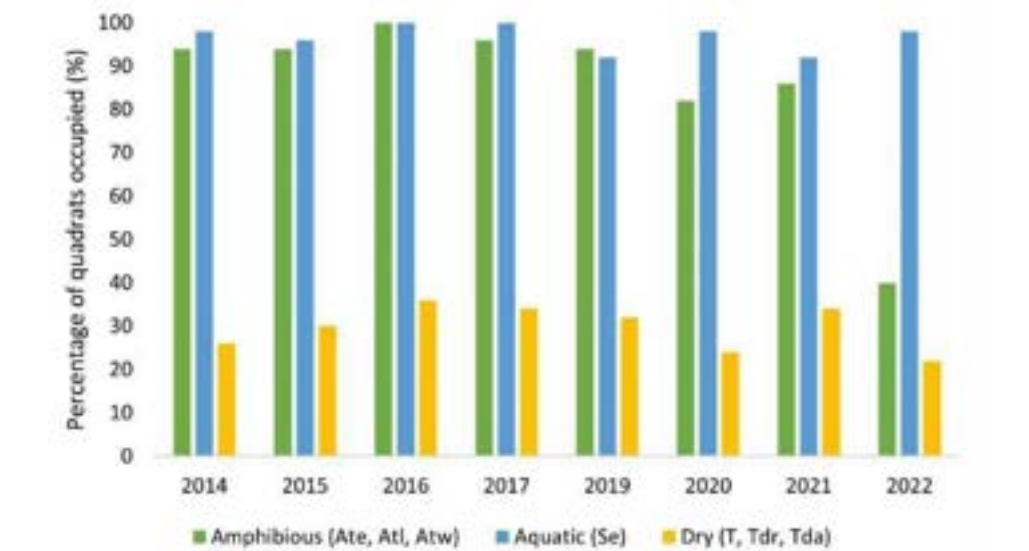
The following site summaries include:

- transect photos at 25 m intervals
- the proportion of each FG recorded at each site
- the top three dominant plant species and their FG
- other attributes including average water depth
- a habitat description
- frog species occurrence and abundance
- water quality data
- relevant comments.

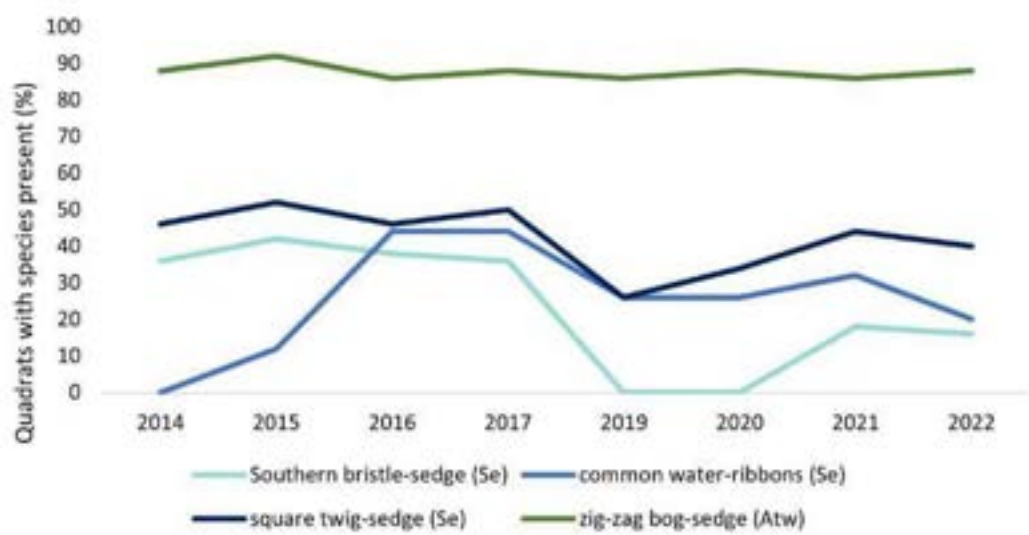
A.



B.



C.



D.

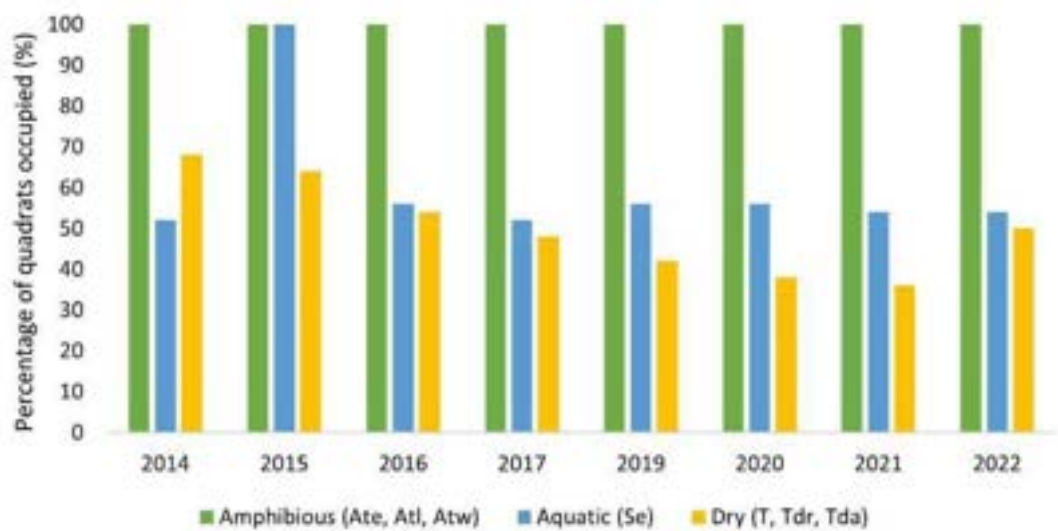
AS2: General habitat description					
Ecological Vegetation Class (EVC)			Aquatic Sedgeland		
Wetland permanence			Ephemeral		
Swamp dominated by emergent dead and live sedges, with patches of clear open water at varying depth to c. 20 cm. Open water contains 5% floating, 5% submergent vegetation and 70-100% emergent vegetation. The swamp is fringed with 70–90% shrub and tree cover with 20 – 50% bare soil.					
AS2: Frog abundance and richness					
Southern Brown Tree Frog		Common Froglet		Southern Bullfrog	
3		11-20		11-15	
				Species Richness	
				3	
AS2: Water quality parameters					
Survey 1					
pH	3.18	Turbidity	1.4 NTU	Water temperature	11 °C
EC	0.642 µs/cm	Salinity	0.3 %	Dissolved Oxygen	3.82 mg/L
Survey 2					
pH	4.29	Turbidity	1.0 NTU	Water temperature	13.4°C
EC	0.29 µs/cm	Salinity	0.1%	Dissolved Oxygen	7.46 mg/L
Comments					
Pools of up to 40 cm depth were present during both surveys which provided relatively good conditions for frogs. Common froglet were heard calling prior to playback. Multiple southern bullfrog (>5) and southern brown tree frog (>3) called in response to call playback during both survey events. Water depth remained relatively constant over both survey events, providing and maintaining suitable habitat for frogs.					

Figure 8 Anglesea Borefield Monitoring and Assessment Program, Anglesea Swamp, Site AS2, 2022 including: A. photo points, B. percentage of quadrats occupied by broad FGs across all monitoring years, C. percentage of top three dominant species across all monitoring years and D. frog summary data.

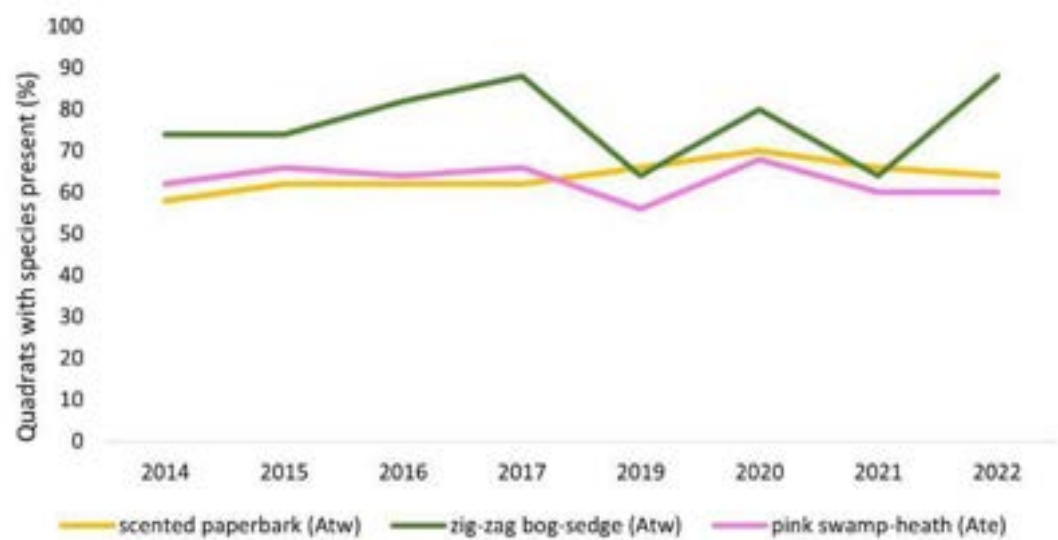
A.



B.



C.



D.

AS3: General habitat description					
Ecological Vegetation Class (EVC)			Swamp Scrub		
Wetland permanence			Semi-permanent		
Site consists of a small (c. 0.25 ha) clearing in shrub vegetation. Emergent vegetation, mainly <i>Juncus sp.</i> , makes up 70–100% of the emerging cover. The shoreline is fringed with <i>Melaleuca</i> species (70-100%). Water was present to a depth of 30 cm during the first survey and dropped slightly to 25 cm by the second frog survey.					
AS3: Frog abundance and richness					
Southern Brown Tree Frog		Common Froglet		Southern Bullfrog	
Species Richness					
6-10		6-10		11-20	
3					
AS3: Water quality parameters					
Survey 1					
pH	4.6	Turbidity	8 NTU	Water temperature	13.5 °C
EC	1.03 µs/cm	Salinity	0.5 %	Dissolved Oxygen	9.7 mg/L
Survey 2					
pH	3.81	Turbidity	3 NTU	Water temperature	8.4 °C
EC	1 µs/cm	Salinity	0.5 %	Dissolved Oxygen	7.41 mg/L
Comments					
Water was adequate for measuring water quality during both surveys. Some frog species were heard during both surveys, with all species heard within 100-m during the second survey. There were additional southern bullfrog calling more than 150-m away on the second survey. The depth remained relatively constant over both survey events, providing suitable habitat for frogs.					

Figure 9 Anglesea Borefield Monitoring and Assessment Program, Anglesea Swamp, Site AS3, 2022 including: A. photo points, B. percentage of quadrats occupied by broad FGs across all monitoring years, C. percentage of top three dominant species across all monitoring years and D. frog summary data.

A.



0 – 25 m



25 – 50 m

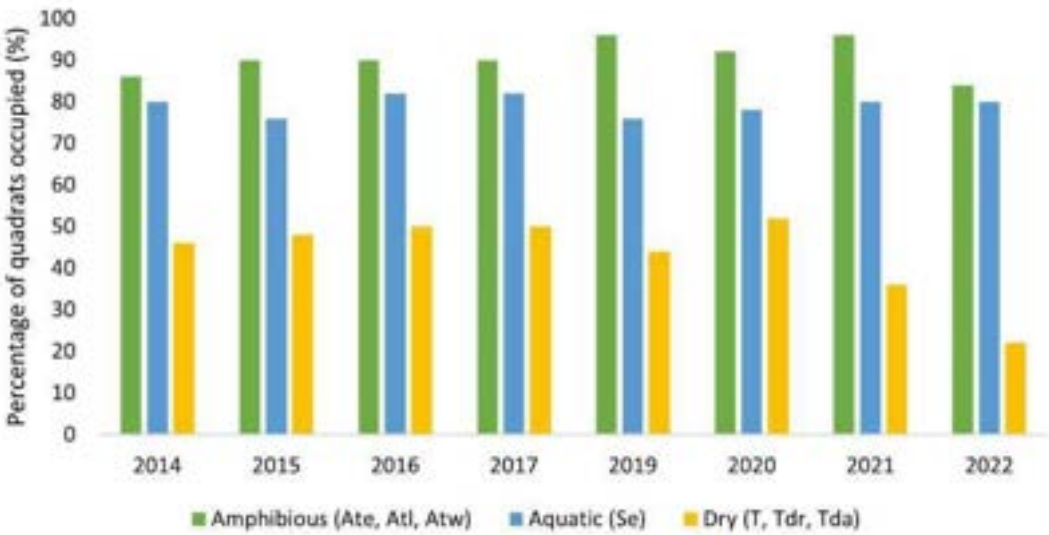


50 – 75 m

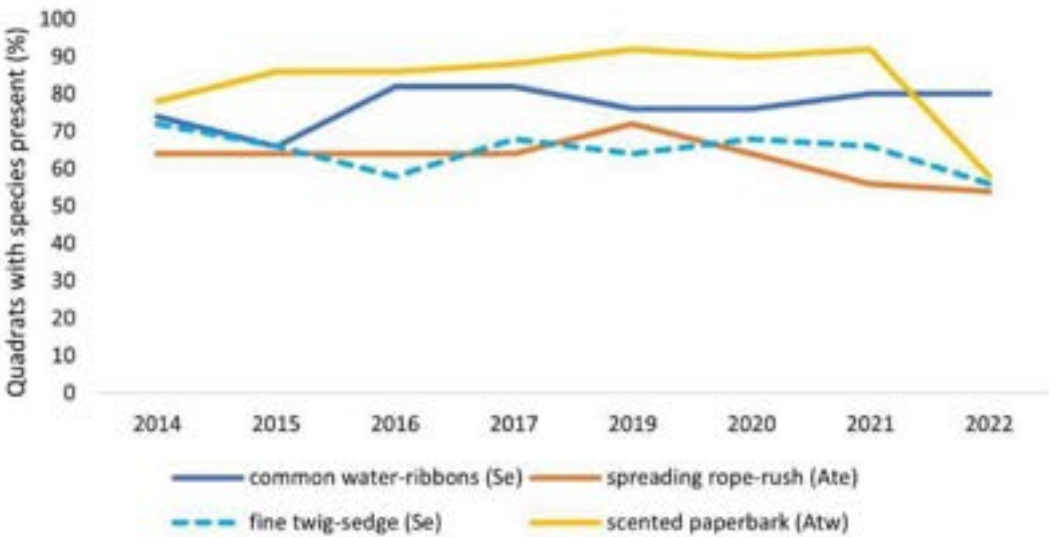


75 – 100 m

B.



C.



D.

AS4: General habitat description					
Ecological Vegetation Class (EVC)			Aquatic Sedgeland		
Wetland permanence			Semi-permanent		
Survey site located on the perimeter of the swamp in fringing vegetation. Depth was adequate (0.4-m) during both surveys. Emergent vegetation of Juncus sp. and scented paperbark (20-50%). Submergent vegetation was absent with fringing vegetation consisting of scented paperbark. There was evidence of off-road driving in the area.					
AS4: Frog abundance and richness					
Southern Brown Tree Frog		Common Froglet		Southern Bullfrog	
-		-		-	
				Species Richness	
				0	
AS4: Water quality parameters					
Survey 1					
pH	3.85	Turbidity	7 NTU	Water temperature	12.4 °C
EC	1.03 µs/cm	Salinity	0.5 %	Dissolved Oxygen	5.4 mg/L
Survey 2					
pH	3.74	Turbidity	11 NTU	Water temperature	14.0 °C
EC	0.93 µs/cm	Salinity	0.5 %	Dissolved Oxygen	7.5 mg/L
Comments					
Frogs were heard calling during each survey but were estimated to be more than 100-m from the site; there were more frogs calling at the time of the second survey. Habitat in the greater area was suitable for frogs.					

Figure 10 Anglesea Borefield Monitoring and Assessment Program, Anglesea Swamp, Site AS4, 2022 including: A. photo points, B. percentage of quadrats occupied by broad FGs across all monitoring years, C. percentage of top three dominant species across all monitoring years and D. frog summary data.

A.



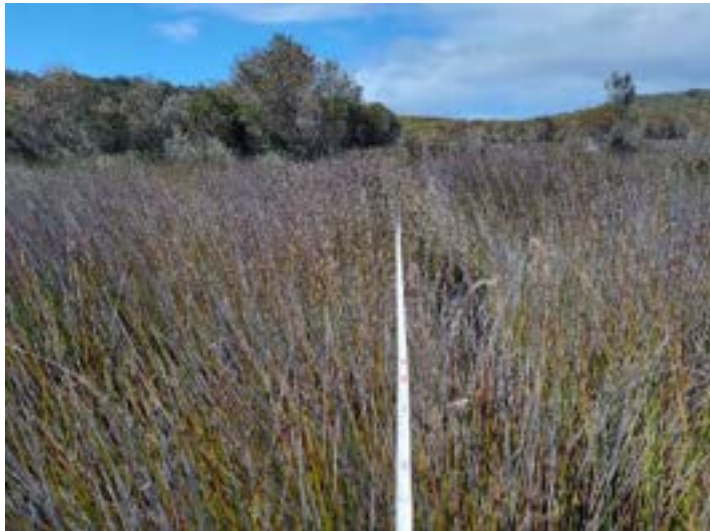
0 – 25 m



25 – 50 m

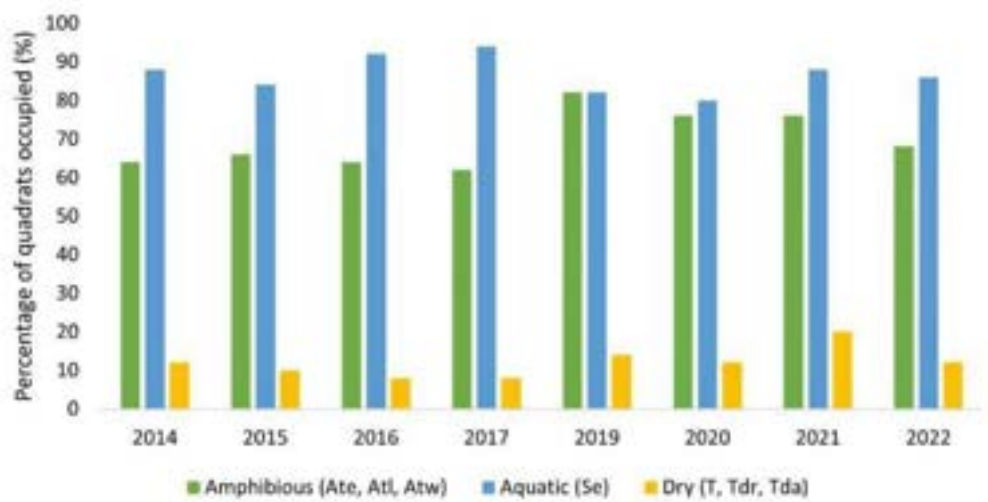


50 – 75 m

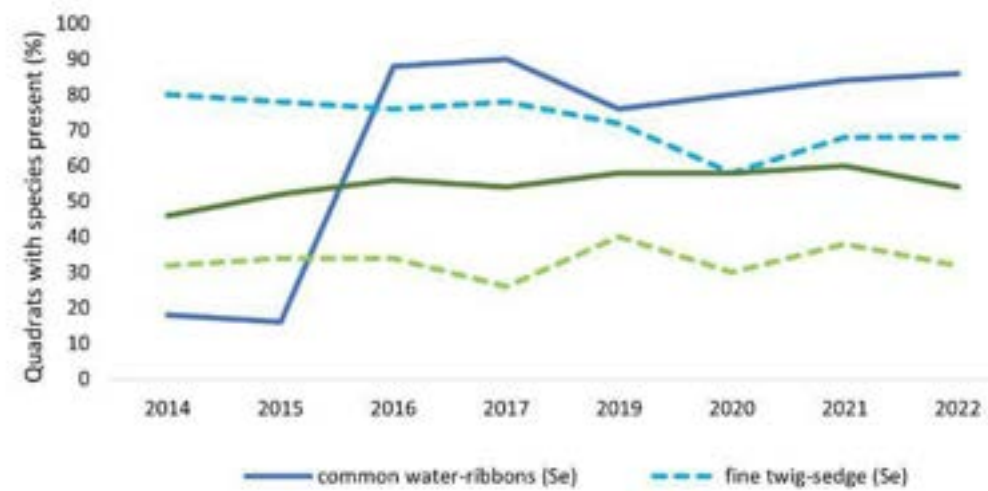


75 – 100 m

B.



C.



D.

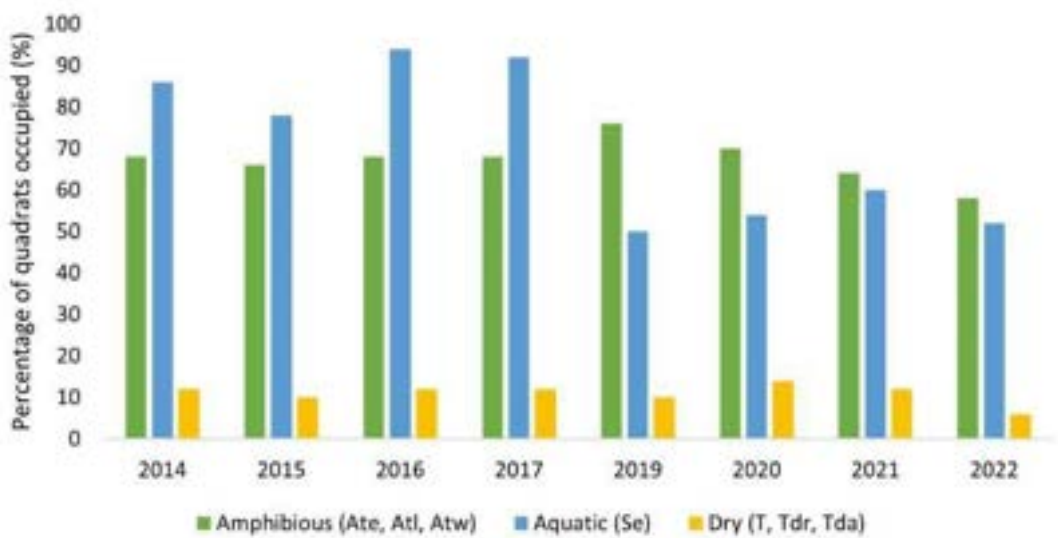
ASP7_2014: General habitat description					
Ecological Vegetation Class (EVC)			Aquatic Sedgeland		
Wetland permanence			Ephemeral		
Site consists of a large (about 3 ha) clearing within the swamp, comprising 50- 70% emergent sedges, fringed with 70-100% cover of mostly scented paperbark. Some submergent (<5%) and floating plants (<5%) were present across both survey the swamp had an average depth of 0.4 m. The substrate consisted of dead and decomposing vegetation.					
ASP7_2014: Frog abundance and richness					
Southern Brown Tree Frog		Common Froglet		Southern Bullfrog	
-		6 –10		3	
				Species Richness	
				2	
ASP7_2014: Water quality parameters					
Survey 1					
pH	3.34	Turbidity	2 NTU	Water temperature	16.7 °C
EC	1.18 µs/cm	Salinity	0.6 %	Dissolved Oxygen	8.63 mg/L
Survey 2					
pH	5.35	Turbidity	22 NTU	Water temperature	17.3 °C
EC	0.76 µs/cm	Salinity	0.4 %	Dissolved Oxygen	5.71 mg/L
Comments					
Despite the suitable water level (0.4-m) the site had high turbidity and elevated water temperature readings. Common froglet were recorded during first (4) and second (8) surveys and three southern bullfrog were detected during the second survey.					

Figure 11 Anglesea Borefield Monitoring and Assessment Program, Anglesea Swamp, Site ASP7_2014, 2022 including: A. photo points, B. percentage of quadrats occupied by broad FGs across all monitoring years, C. percentage of top three dominant species across all monitoring years and D. frog summary data.

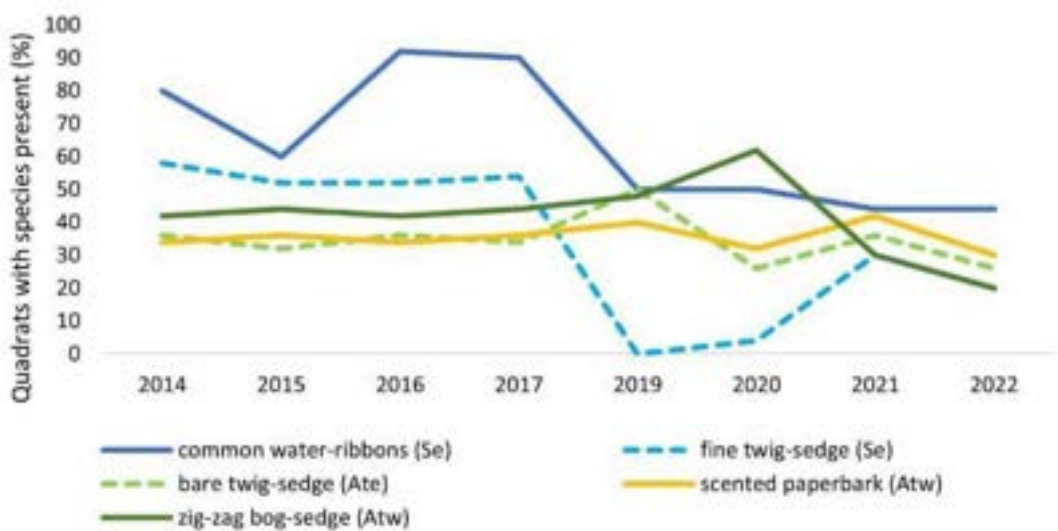
A.



B.



C.



D.

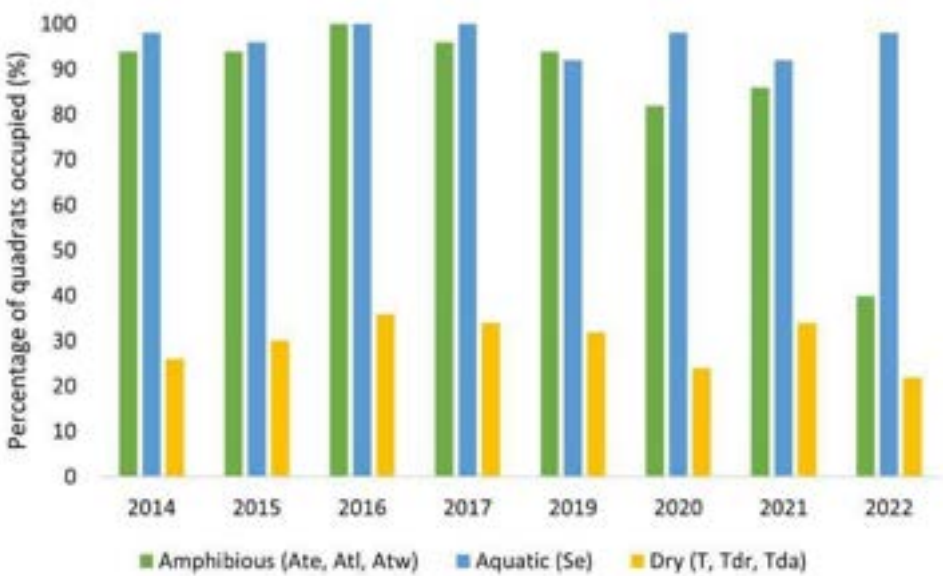
AS1_2014: General habitat description					
Ecological Vegetation Class (EVC)			Aquatic Sedgeland		
Wetland permanence			Ephemeral		
This mostly open swamp area is almost extensively fringed with scented paperbark and prickly tea-tree consisting of 70–100%. Floating and submergent vegetation absent. Emergent rushes (20–50%) are located throughout the swamp. The water level was sufficient (>0.35-m) for water quality measurements during both surveys.					
AS1_2014: Frog abundance and richness					
Southern Brown Tree Frog		Common Froglet		Southern Bullfrog	
2		11-20		12	
				3	
AS1_2014: Water quality parameters					
Survey 1					
pH	5.27	Turbidity	5 NTU	Water temperature	16.0 °C
EC	1.01 µs/cm	Salinity	0.5 %	Dissolved Oxygen	7.04 mg/L
Survey 2					
pH	3.86	Turbidity	28 NTU	Water temperature	20.6 °C
EC	0.86 µs/cm	Salinity	0.4 %	Dissolved Oxygen	6.2 mg/L
Comments					
Common froglet and southern bullfrog heard calling at site during both surveys; southern tree frogs were only detected during the first survey. There were no frogs detected in either survey.					

Figure 12 Anglesea Borefield Monitoring and Assessment Program, Anglesea Swamp, Site AS1_2014, 2022 including: A. photo points, B. percentage of quadrats occupied by broad FGs across all monitoring years, C. percentage of top three dominant species across all monitoring years and D. frog summary data.

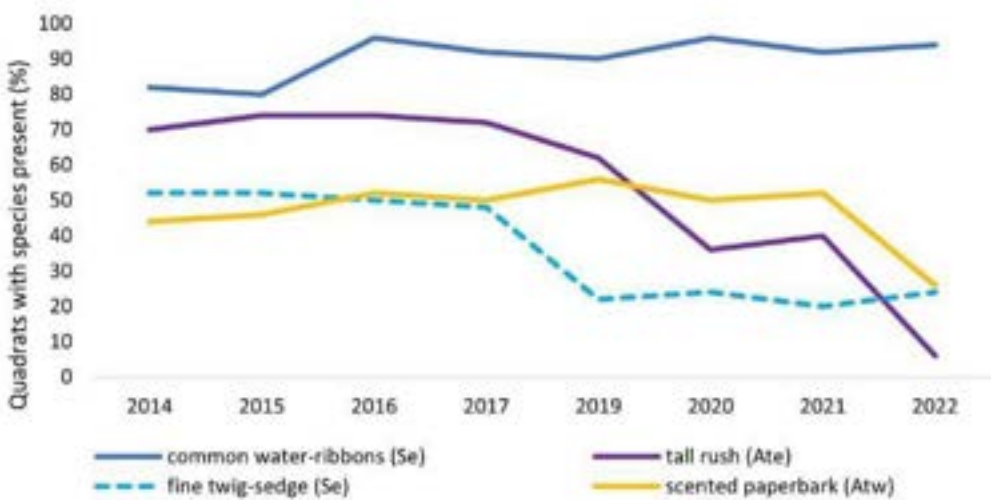
A.



B.



C.



D.

AGP2_2014: General habitat description					
Ecological Vegetation Class (EVC)			Aquatic Sedgeland		
Wetland permanence			Ephemeral		
A small (c. 0.25 ha) clearing in tall (up to 4 m) fringing vegetation of scented paperbark and prickly tea-tree (70-100%). Approximately 40% open water with 10-20% cover of floating common water-ribbons, interspersed with emergent rushes (Juncus spp.) and patches of scented paperbark. Emergent vegetation consisted of Gahnia, common water-ribbon, and rushes (50-70%), with submergent common water-ribbon (5-10%).					
AGP2_2014: Frog abundance and richness					
Southern Brown Tree Frog		Common Froglet		Southern Bullfrog	Species Richness
2		6-10		4	3
AGP2_2014: Water quality parameters					
Survey 1					
pH	3.18	Turbidity	1 NTU	Water temperature	12.5 °C
EC	0.96 µs/cm	Salinity	0.5 %	Dissolved Oxygen	8.39 mg/L
Survey 2					
pH	3.36	Turbidity	0 NTU	Water temperature	15.4 °C
EC	0.66 µs/cm	Salinity	0.3 %	Dissolved Oxygen	6.4 mg/L
Comments					
Frogs were only detected at the site during the first survey. All frogs detected during second survey were more than 200-m from the site.					

Figure 13 Anglesea Borefield Monitoring and Assessment Program, Anglesea Swamp, Site AGP2_2014, 2022 including: A. photo points, B. percentage of quadrats occupied by broad FGs across all monitoring years, C. percentage of top three dominant species across all monitoring years and D. frog summary data.

AS5: General habitat description						
Ecological Vegetation Class (EVC)			Aquatic Sedgeland			
Wetland permanence			Ephemeral			
The small (0.25 ha) section of swamp was generally moist with occasional deeper depressions. The vegetation, consists of sedges surrounded by 70–100% cover of fringing prickly tea-tree and scented paperbark.						
AS5: Frog abundance and richness						
Southern Brown Tree Frog		Common Froglet		Southern Bullfrog		Species Richness
2		3		3		3
AS5: Water quality parameters						
Survey 1						
pH	3.72	Turbidity	1 NTU	Water temperature		12.1 °C
EC	0.79 µs/cm	Salinity	0.4 %	Dissolved Oxygen		3.87 mg/L
Survey 2						
pH	3.96	Turbidity	2.4	Water temperature		14.2
EC	0.57	Salinity	0.3 %	Dissolved Oxygen		7.2
Comments						
Water levels (0.4 m) enabled water quality measurements during both surveys. Southern bullfrog and common froglet were detected calling at the site during the first survey, with 5–10 SBTF heard calling >200 m from the site. In survey 2, only SBTFs and common froglet were heard calling at the site; 3 southern bullfrogs were heard calling >200 m from the site.						

Figure 14 Anglesea Borefield terrestrial revised ecological Monitoring and Assessment Program, Anglesea Swamp site AS5, 2022 frog summary data.

AS6: General habitat description					
Ecological Vegetation Class (EVC)			Aquatic Sedgeland		
Wetland permanence			Ephemeral		
Swamp relatively shallow (to 0.15 m) consisting of emergent (10–20%) vegetation consisting of decomposing sedges, small clumps of live sedges and scented paperbark. Submergent and floating vegetation was absent with the swamp fringed by 70–100% of scented paperbark. Water depth was sufficient across both surveys, being 0.2 m at the time of first survey; this had increases to 0.3 m by the time of the second survey.					
AS6: Frog abundance and richness					
Southern Brown Tree Frog		Common Froglet		Southern Bullfrog	Species Richness
0		11-20		0	1
AS6: Water quality parameters					
Survey 1					
pH	3.25	Turbidity	1 NTU	Water temperature	13.5 °C
EC	0.89 µs/cm	Salinity	0.4 %	Dissolved Oxygen	7.22 mg/L
Survey 2					
pH	3.49	Turbidity	0 NTU	Water temperature	16.9 °C
EC	0.62 µs/cm	Salinity	0.3 %	Dissolved Oxygen	6.3 mg/L
Comments					
Despite the sufficient water levels across at the site, frog diversity was relatively low with 11–20 common froglet calling when arriving at the site in survey one, with <5 SBTF calling from more than 200 m away. At the time of the second survey, 11–20 common froglet were heard calling at site, with 4 southern bullfrogs calling 200 m from site.					

Figure 15 Anglesea Borefield terrestrial revised ecological Monitoring and Assessment Program, Anglesea Swamp site AS6, 2022 frog summary data.

LAR1 vegetation and frog summary data

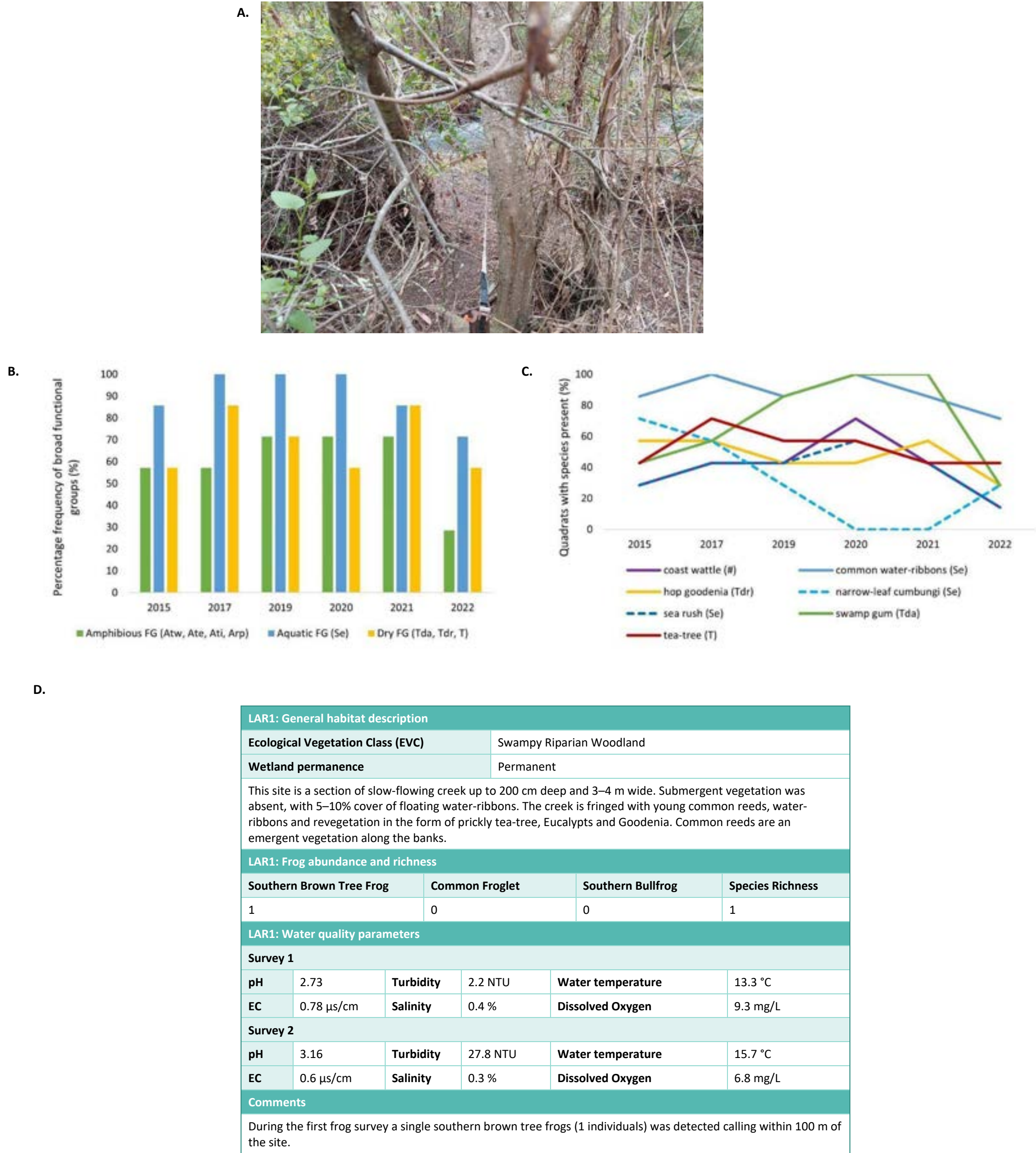


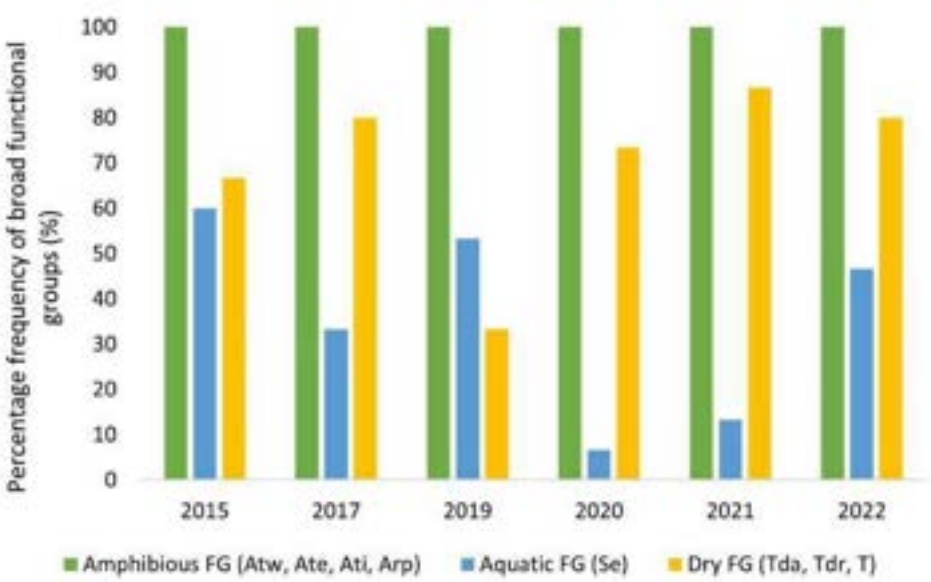
Figure 16 Anglesea Borefield Monitoring and Assessment Program, Anglesea Estuary, Site LAR1, 2022 including: A. photo points, B. percentage of quadrats occupied by broad FGs across all monitoring years, C. percentage of top three dominant species across all monitoring years and D. frog summary data.

LAR2 vegetation and frog summary data

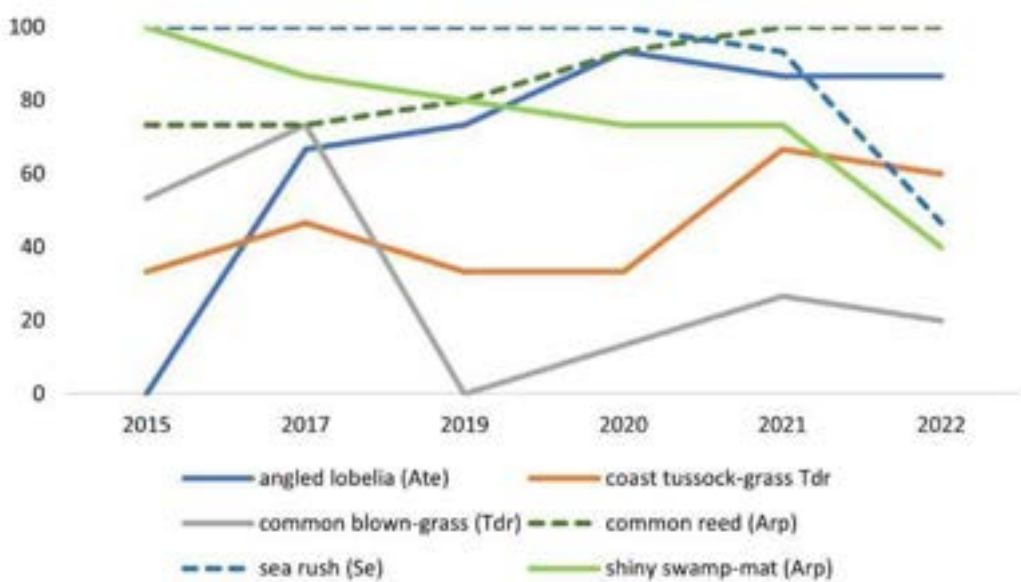
A.



B.



C.

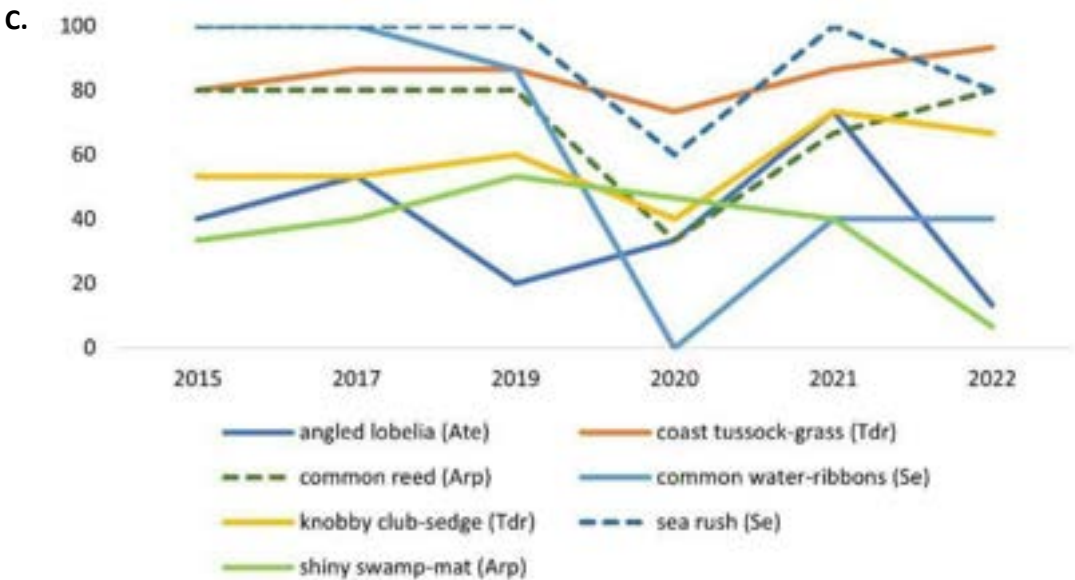


D.

LAR2: General habitat description					
Ecological Vegetation Class (EVC)			Estuarine Woodland		
Wetland permanence			Permanent		
Slow-moving section of creek in estuary with depths of 1–2 m and 7–8 m wide. This section is fringed with 70–100% cover of angled lobelia, coastal tussock-grass, sea rush and common reed. There was no submergent or floating vegetation present. The site is mostly open, supporting less than 5% cover of emergent vegetation. A formed walking path runs along the edge of the waterway.					
LAR2: Frog abundance and richness					
Southern Brown Tree Frog		Common Froglet		Southern Bullfrog	
-		-		-	
				Species Richness	
				0	
LAR2: Water quality parameters					
Survey 1					
pH	3.38	Turbidity	1.1 NTU	Water temperature	15.3 °C
EC	6.57 µs/cm	Salinity	3.6 %	Dissolved Oxygen	8.5 mg/L
Survey 2					
pH	4.12	Turbidity	0 NTU	Water temperature	15.5 °C
EC	6.5 µs/cm	Salinity	3.5 %	Dissolved Oxygen	6.15 mg/L
Comments					
During the first survey, 3 southern brown tree frogs were heard calling more than 300 m away from the site. There were no frogs detected calling during either survey from within 100 m of the site in either survey.					

Figure 17 Anglesea Borefield Monitoring and Assessment Program, Anglesea Estuary, Site LAR2, 2022 including: A. photo points, B. percentage of quadrats occupied by broad FGs across all monitoring years, C. percentage of top three dominant species across all monitoring years and D. frog summary data.

LAR3 vegetation and frog summary data



D.

LAR3: General habitat description					
Ecological Vegetation Class (EVC)			Estuarine Woodland		
Wetland permanence			Permanent		
This site is dominated by a slow-flowing creek 10–12 m wide, 1 – 1.5 m deep. There is an absence of emergent and floating vegetation. Emergent vegetation formed <5% of the area. The site is fringed by 70–100% cover of dominated by <i>Juncus</i> .					
LAR3: Frog abundance and richness					
Southern Brown Tree Frog		Common Froglet		Southern Bullfrog	
0		0		0	
Species Richness					
0					
LAR3: Water quality parameters					
Survey 1					
pH	3.8	Turbidity	1.4 NTU	Water temperature	15 °C
EC	2.6 µs/cm	Salinity	1.3 %	Dissolved Oxygen	8.74 mg/L
Survey 2					
pH	4.05	Turbidity	41.6 NTU	Water temperature	15.7 °C
EC	3.18 µs/cm	Salinity	1.6 %	Dissolved Oxygen	6.36 mg/L
Comments					
During both survey, 3 southern brown tree frogs were heard calling greater than 300 m away from the site. There were no frogs detected during calling from within 100 m of the site in either survey.					

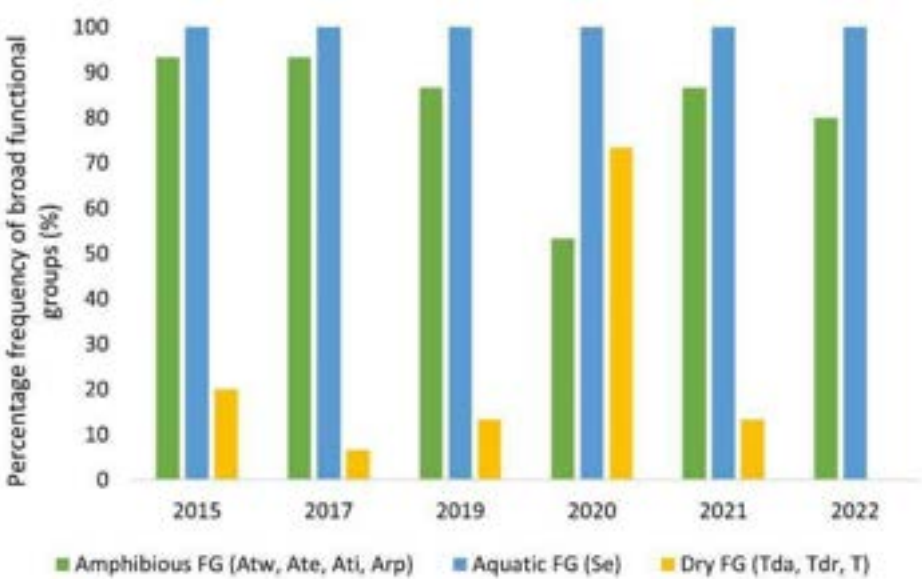
Figure 18 Anglesea Borefield Monitoring and Assessment Program, Anglesea Estuary, Site LAR3, 2022 including: A. photo points, B. percentage of quadrats occupied by broad FGs across all monitoring years, C. percentage of top three dominant species across all monitoring years and D. frog summary data.

LAR4 vegetation and frog summary data

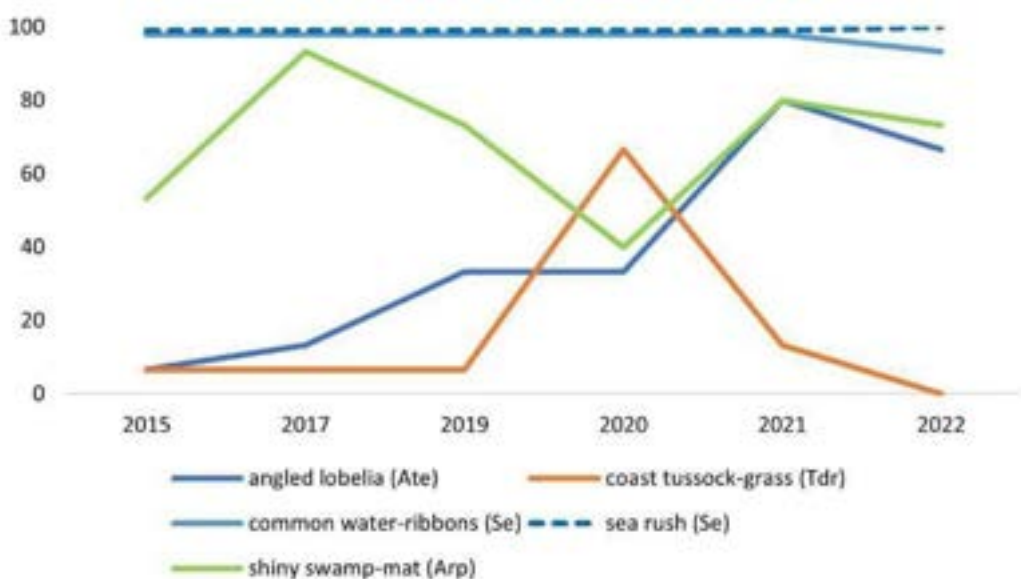
A.



B.



C.



D.

LAR4: General habitat description					
Ecological Vegetation Class (EVC)			Heathy Woodland		
Wetland permanence			Permanent		
This section of the creek site is 10–12 m wide and up to 2 m deep. The site is fringed by revegetation (70–100%) along the west bank consisting of: Goodenia and prickly tea-tree with some other species forming an understorey. The east bank is vegetated with sea rush, dead common reed and coastal tussock-grass. Submergent and floating plants were absent with less than 5% of the area covered with emergent vegetation.					
LAR4: Frog abundance and richness					
Southern Brown Tree Frog		Common Froglet		Southern Bullfrog	
0		0		0	
Species Richness		0			
LAR4: Water quality parameters					
Survey 1					
pH	3.28	Turbidity	0.7 NTU	Water temperature	15.6 °C
EC	3.92 µs/cm	Salinity	2.1 %	Dissolved Oxygen	7.9 mg/L
Survey 2					
pH	3.24	Turbidity	43 NTU	Water temperature	16.1 °C
EC	5.05 µs/cm	Salinity	2.7 %	Dissolved Oxygen	6.3 mg/L
Comments					
During both surveys, 3 southern brown tree frogs were detected calling more than 300 m away from the site. A single common froglet was heard calling from more than 100 m from the site during the second survey. There were no other frog species detected during calling from within 100 m of the site in either survey.					

Figure 19 Anglesea Borefield Monitoring and Assessment Program, Anglesea Estuary, Site LAR4, 2022 including: A. photo points, B. percentage of quadrats occupied by broad FGs across all monitoring years, C. percentage of top three dominant species across all monitoring years and D. frog summary data.

3.3 Macroinvertebrates

The macroinvertebrate results based on combined sample data from each site are provided in Table 6. Due to the very wet winter/spring in 2022, all sites had sufficient wetted habitat to collect triplicate edge samples. No site met the objective for number of families either for the creek or wetland sites listed in the Environmental Reference Standard (ERS) (Vic. Gov. 2021) (Table 6). The Salt Creek site was more diverse (based on Number of Families) than the Breakfast Creek sites, which was more diverse than the wetland site. SIGNAL2 objectives were potentially met (refer to limitations section 2.3.1) for both the Breakfast Creek and Salt Creek sites. The VLAKES objective was not met for the wetland site. The EPT index objective was not met for any of the 3 sites. As no Odonata were detected at any sites in 2022, the EPT and EPTO results are the same. Individual sample results from each site are presented in section 3.7.

Table 6 Site macroinvertebrate indices result from all sites, combining the 3 edge samples taken (potential attainment of ERS objectives indicated by green and non-attainment by red). Environmental reference standards (ERS) objectives for streams and rivers in Central Foothills and Coastal Plains (creek) were compared with BCT1 and SC1 and objectives for shallow inland wetlands with outflow (wetland) were compared with W2/3.

Index	BCT1	SC1	W2/3	ERS objective*
# families (creek)	11	15	-	20
SIGNAL2	5.5	5.0	-	3.4
# families (wetland)	-	-	6	15
VLAKES	-	-	4.0	4.3
EPT	3	4	1	-
EPTO	3	4	1	-

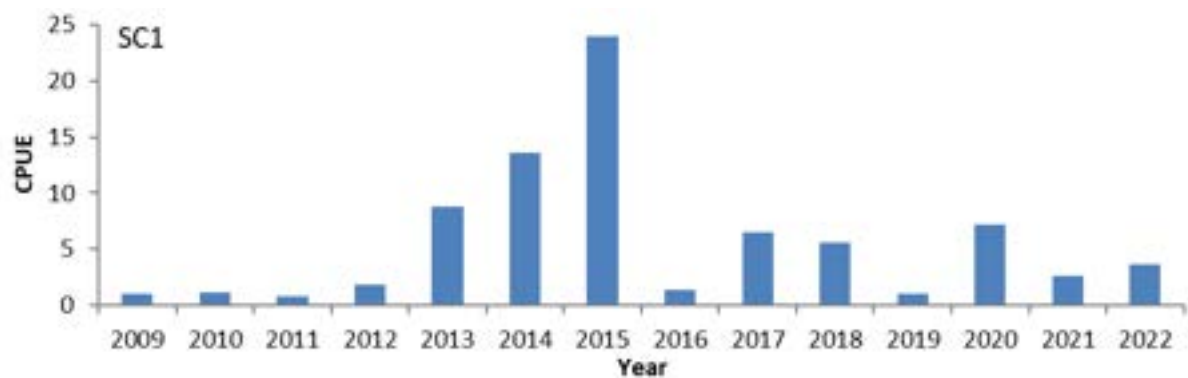
3.4 Southern Pygmy Perch

A total of 41 southern pygmy perch were captured from Salt Creek (SC1), and none were captured from Breakfast Creek tributary (Figure 20–Figure 21). Southern pygmy perch were captured both within the bait traps (37) and during the sweep netting (4). In 2022, southern pygmy perch Catch Per Unit Effort (CPUE) was higher than that recorded in the previous year (2021) but remains broadly comparable with the CPUE of the past 5 years (2018–2022) (Figure 21). No young-of-year fish (i.e. fish considered to be less than one year of age) were detected at SC1 in 2022, indicative of potential recent recruitment failure (i.e. failure to breed or for larval and juvenile fish to survive). Young-of-year fish were last recorded at SC1 in 2021. Observations of the fish colouration and condition (some were ‘running ripe’) at time of capture suggests that breeding was occurring or imminent in 2022. There was a possible bias towards capture of males at this site in 2022, with 12 females and 29 males captured.

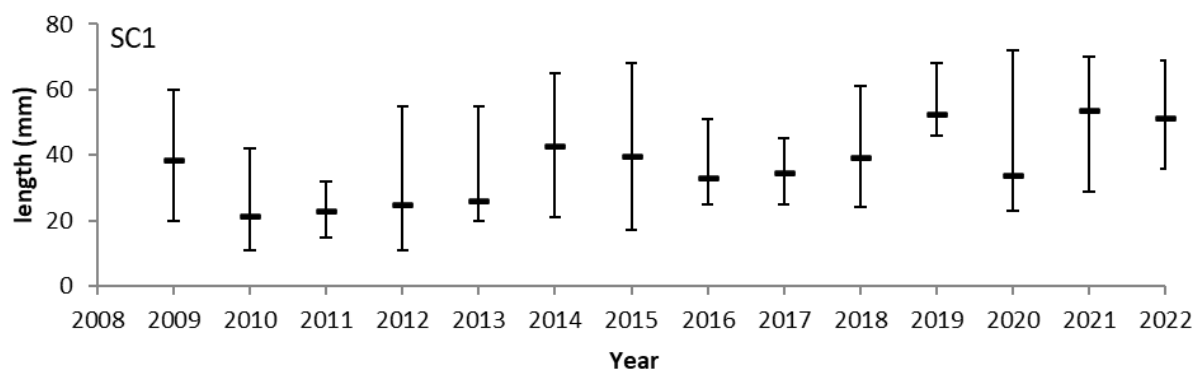
2022 represents the fifth consecutive year that southern pygmy perch were not recorded at the Breakfast Creek tributary site, following indications of recruitment failure in 2017 (Ecology Australia 2017), strongly suggesting local extirpation.



Figure 20 Southern pygmy perch (male top & female bottom) from Salt Creek in 2022.



a) Fish Catch Per Unit Effort (CPUE; fish per trap) of southern pygmy perch at site SC1.



b) Mean (black bars), together with minimum and maximum lengths (TL) of southern pygmy perch.

Figure 21 Site SC1 southern pygmy perch spring CPUE (a) and length (b) summaries 2009–2022.

Note: CPUE and length graphs for BCT1 have not been re-created for 2022 as no southern pygmy perch were detected for the fifth year in a row, for historical CPUE and length graphs please see Ecology Australia, (2022).

3.5 Otway Bush Yabby

Otway bush yabby *Geocharax tasmanicus* is a small freshwater crayfish listed as Endangered under the FFG Act 1988 and has been annually detected at Salt Creek and Breakfast Creek sites since 2017 (Ecology Australia 2018–2022). The species was again detected at Salt Creek and Breakfast Creek sites in 2022, by bait trapping and sweep netting in Breakfast Creek, but only by sweep netting in Salt Creek. A total of 48 Otway bush yabbies were captured in 2022, 46 from Breakfast Creek (bait traps = 16, sweep net = 30) and two from Salt Creek.



Figure 22 Multiple size classes of Otway bush yabby from Breakfast Creek during the 2022 fish surveys.

3.6 Water quality

Water quality results were consistent with results from previous years (GHD 2010–17, Ecology Australia 2018–2022; Table 7). It should be noted that water quality results are highly variable within short temporal periods, and that to assess against ERS indices, a minimum of 11 data points is required from a single year (i.e. to calculate annual percentiles). Thus, results are only compared with the ERS objectives to provide context. For both Breakfast Creek and Salt Creek, conductivity, dissolved oxygen and turbidity were at levels that would potentially meet ERS objectives, however, pH was considerably lower than the objectives, more so in Breakfast Creek than Salt Creek (Table 7). Wetland 2/3 would potentially meet the ERS objective for turbidity but would potentially fail to meet the objective for dissolved oxygen and pH.

Table 7 *In situ* water quality results and environmental reference standard (ERS) objectives for streams and rivers in Central Foothills and Coastal Plains (creek) and for shallow inland wetlands with outflow (wetland). Potential attainment of ERS objectives indicated by green and potential non-attainment by red.

Objective/site	Temp (°C)	Conductivity (ms/cm@25oC)	Dissolved oxygen		pH	Turbidity (NTU)
			mg/L	%Sat		
ERS (creek)	N/a	≤2.0	N/a	≥70	6.8–8	≤25
BCT1	11.28	0.197	10.74	101.3	2.75	12
SC1	12.39	0.263	10.43	101	6.21	9.7
ERS (wetland)	N/a	N/a	N/a	80-120	6.5-8.5	15
W2/3	12.25	0.868	7.48	10.9	1.84	3.3

3.7 Aquatic monitoring sites

3.7.1 Breakfast Creek and tributaries

Breakfast Creek tributary site BCT1 consisted of a narrow, shallow stream, with a maximum width of 1.5 m (Figure 23). During the 2022 surveys BCT1 there was a moderate flow passing over the V-notch weir. The substrate was predominantly silt/clay, with some sand, pebble and gravel present. The main instream cover available for fish and macroinvertebrates, in decreasing order of prevalence, consisted of coarse particulate organic matter (e.g. leaves and other organic debris), undercut banks, overhanging terrestrial vegetation, woody debris, filamentous algae and roots.



Figure 23 Breakfast creek in 2022, photo taken at BCT1 V-notch gauge.

The Breakfast Creek tributary site surveyed attained ERS objectives for SIGNAL2 scores for all 3 samples (Table 9). No other objectives were achieved. The SIGNAL2 score and number of different families are similar to the last several years of the project with both showing an increase in 2022 compared with 2021, however the overall trend since 2014 has been decline for both indices (Figure 24). The EPT taxa again make up a good proportion of the total number of families detected and continue to drive up SIGNAL2 scores for Breakfast Creek.

Table 8 Individual macroinvertebrate sample indices results for Breakfast Creek tributary site 1, showing ERS objectives (attainment of ERS objectives indicated by green and non-attainment by red).

Index	Breakfast Creek Tributary site 1			ERS objective
	Edge sample 1	Edge sample 2	Edge sample 3	
Abundance	26	16	39	-
# Families	9	4	8	20
SIGNAL2	5.8	5.5	6.1	3
EPT	3	2	3	-
EPTO	3	2	3	-

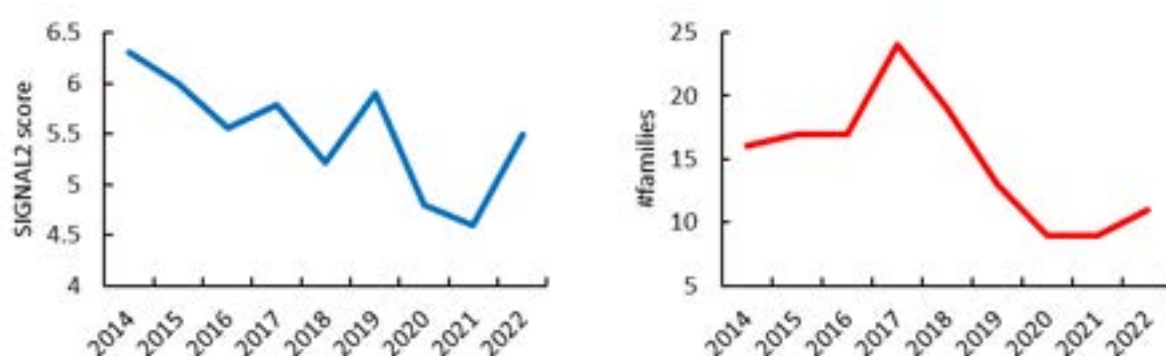


Figure 24 Yearly average SIGNAL2 scores and number of families at site BCT1 from 2014–2022 (no survey occurred in 2019).

No southern pygmy perch were detected at BCT1 during this round of monitoring. This is the fifth year in a row that this species has not been detected at BCT1. Recruitment failure was evident at this site in 2017 (Ecology Australia 2017), with consecutive years of non-detection now being indicative of local extirpation.

Otway bush yabby were captured in greater abundance in 2022 compared with 2021. A significant proportion were juvenile, and this suggests recent recruitment success. Individuals ranged in size from 4–21 mm Occipital Carapace Length (OCL) (Figure 25).

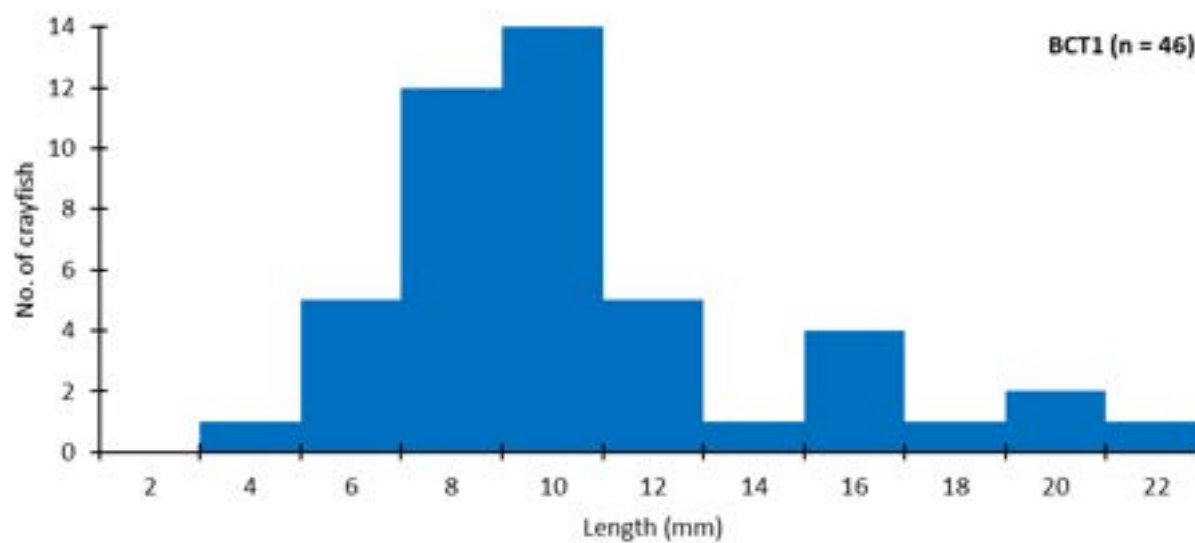


Figure 25 Length-frequency histogram for the 2022 Otway bush crayfish captured at Breakfast Creek site BCT1.

3.7.2 Salt Creek

The Salt Creek site consists primarily of a large and relatively deep permanent pool, located on an otherwise small and relatively shallow channel (Figure 26). Based on observations since 2017, this site should be considered a likely permanent refuge. The substrate was silt/clay and there was water flowing into and out of the large pool at a moderate velocity. Compared with previous years (especially 2017–2020) the areas of lentic habitat were reduced, and flow was visible from the pool entrance to exit. The amount of loose silt appeared similar to that of 2021, which was greatly reduced on previous years. Aquatic macrophytes remain absent from the pool.



Figure 26 Salt Creek in 2022 at site SC1.

The Salt Creek site attained ERS objectives for SIGNAL2 score for all 3 edge samples (Table 10). No other relevant objectives were achieved. The SIGNAL2 scores and number of families represent a slight improvement in the 2022 compared with the 2021 but the overall trend of the past few years has been decline compared with the 2014–2019 period (Figure 27).

Table 9 Individual macroinvertebrate sample results for Salt Creek, showing ERS objectives (attainment of ERS objectives indicated by green and non-attainment by red).

Index	Salt Creek site 1			ERS objective
	E1	E2	E3	
Abundance	12	39	31	-
# Families	5	11	9	20
SIGNAL2	4.0	4.7	4.9	3.4
EPT	0	3	1	-
EPTO	0	3	1	-

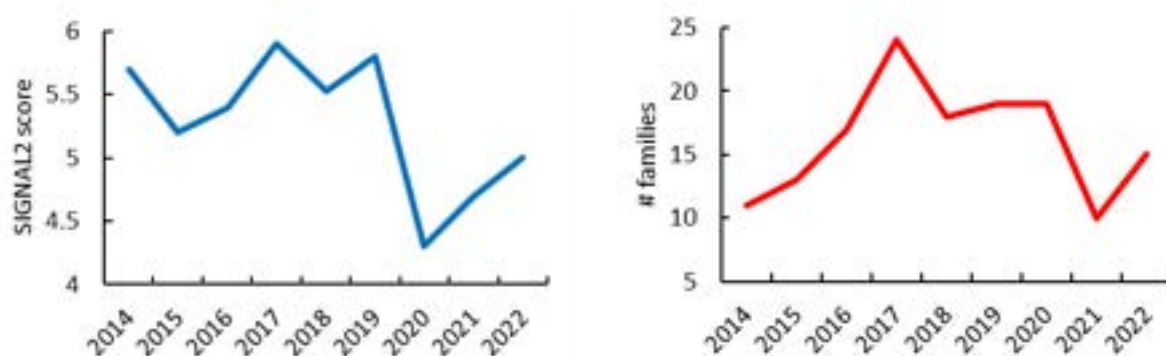


Figure 27 Yearly average SIGNAL2 scores and number of families at site SC1 from 2014–2022.

As outlined in section 3.4, southern pygmy perch were detected in comparable abundance to the previous five years. The length-weight frequency plot shows the population was between 35–70 mm, with more males (29) than females (12) (Figure 28).

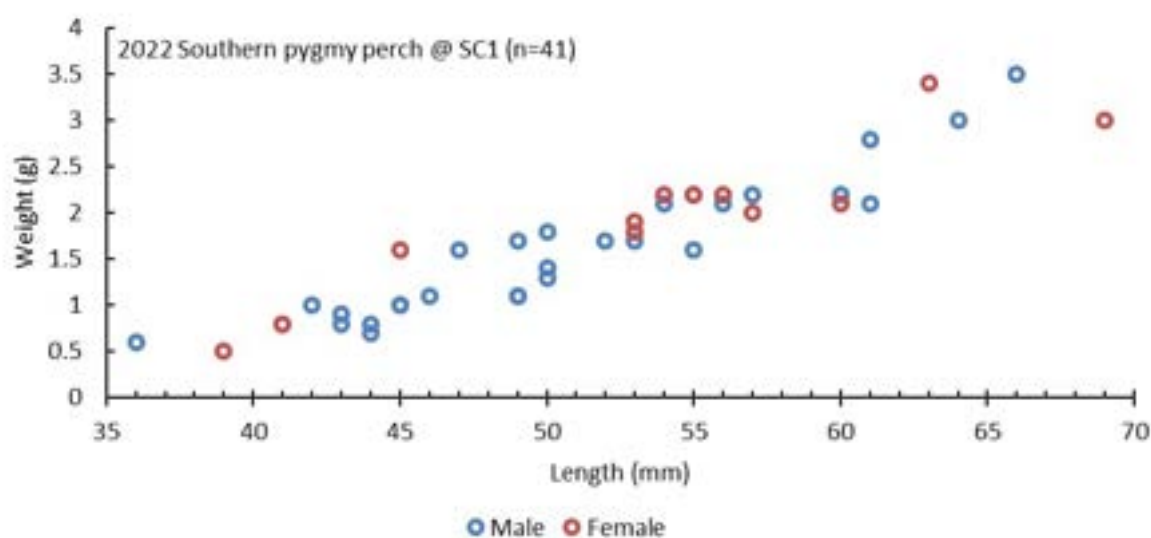


Figure 28 Length-weight plot for the 2022 southern pygmy perch, including sex, captured at Salt Creek site SC1.

Otway bush yabby were present at Salt Creek in 2022 in low abundance. The species was not detected with bait traps and only 2 individuals (16 mm OCL female and 7 mm OCL juvenile) were captured using sweep netting. There appears to have been a reduction in abundance of this species at this site since 2020.

3.7.3 Lower Anglesea River Wetlands

There were obvious visual differences in the water levels and filamentous algae cover at the Lower Anglesea River wetland 2/3 in 2022 compared the 2017–2022 period (Figure 29). The pool at wetland 2 was larger, slowly flowing (instead of still) and had an increased aquatic vegetation cover (*Triglochin* sp.). The cover of filamentous algae, which entirely dominated the pool (near 100% coverage) in previous years, was at about 40–50% coverage. Wetland 3 was also larger than during sampling events in previous years, with higher flows and overbank flows occurring (*Juncus* sp., paperbark and tea-tree were flooded throughout the site). The substrate was predominantly clay/silt. Some water was also flowing across the track at the time of survey at two locations. No southern pygmy perch or Otway bush yabby were detected at this time, consistent with the findings of previous years.



a) 2022



b) 2021



c) 2020

Figure 29 Lower Anglesea River wetland 2 site in 2022 (a) compared with 2021 (b) and 2020 (c).

The Wetland 2/3 site attained the VLAKES objective for 2 of the 3 samples (Table 11). No other relevant objectives were achieved. The macroinvertebrate assemblage at this site appeared to have marginally declined compared with 2021 and 2019 but was similar to that of 2020. No Otway bush yabbies were detected at any of the Lower Anglesea River wetland sites, consistent with the findings of previous years.

Table 10 Individual macroinvertebrate sample results for lower Anglesea River wetland 2/3, showing ERS objectives (attainment of ERS objectives indicated by green and non-attainment by red).

Index	Lower Anglesea River Wetland site 2/3			ERS objective
	E1	E2	E3	
Abundance	79	9	13	-
# Families	6	2	3	15
VLAKES	4.2	5.5	5.3	4.3
EPT	1	0	0	-
EPTO	1	0	0	-

4 Discussion

4.1 Vegetation

In the Anglesea Swamp sites, overall species richness within the wetland communities (Aquatic Sedgeland EVC and Swamp Scrub EVC) increased by one species from the previous year. Dominant species remained present at all sites, however some dominant species (tall rush and scented paperbark) decreased in frequency substantially at AGP2_2014 from 2021. Both these species require the presence of water for most of the year. The swamp at AGP2_2014 is an ephemeral wetland, however based on water depth at the site (average 18.9 cm) and above average mean rainfall, it is unlikely this site dried out substantially between the 2021 and 2022 surveys. Since the revised MAP commenced, the total number of species has decreased across 5 of the 6 sites in the Anglesea Swamp. Partly, this reduction in species can be explained by a decrease in several species which are associated with drier vegetation of the Heathy Woodland and Swamp Scrub EVC interface. Site AS4 has displayed a reduction of several species which contribute very little cover to the overall transect and are not predictive of changes to either the Swamp Scrub EVC or the Aquatic Sedgeland EVC.

In the Anglesea Estuary sites, native species richness remained relatively stable at LAR1, 2 and 3 and the variation displayed is within expected ranges of annual variation. However, site LAR4 has decreased in total number of species since the revised MAP commenced. In particular, this site has exhibited a significant trend of decreased species richness since 2020. The species which have no longer been recorded in LAR4 all contributed to only 1 or 2 quadrats in total and their disappearance from the transect is unlikely due to hydrological changes. Weed species were only recorded the LAR2 Estuary site (Appendix 2). Native plant species continue to be recorded in higher numbers and higher frequencies than weeds since monitoring in the estuary began (see Ecology Australia 2015, 2017, 2019, 2020 and 2021).

Overall, the proportion of aquatic functional groups has remained relatively stable across all sites between 2014 and 2022. However, the proportion of aquatic functional groups decreased substantially between 2017 and 2019, before steadily increasing between 2019 and 2022. Aquatic species are highly sensitive to changes in hydrology as they require permanent water in their root zone to survive (Cassanova 2011 and Doeg et.al. 2012). The 2022 rainfall data from Aireys Inlet recorded average annual rainfall as 631 mm from 1994 to 2021 (BOM 2022). Both 2014 (498 mm) and 2015 (488 mm) were relatively dry years and little to no standing water was present across all sites (Ecology Australia 2014, Ecology Australia 2015). Following this was 2 years of above or near average rain fall in 2016 (714 mm) and 2017 (609 mm), during which time the Aquatic functional groups showed little change in abundance. By contrast, yearly rainfall decreased in 2019 to 525 mm and as a result, the Aquatic functional groups dropped approximately 20% across all sites. Yearly rainfall across 2020 (713 mm) and 2021 (726 mm) was higher than average, which is likely resulting in the increased proportion of aquatic species recorded during this time.

Across most Anglesea Swamp sites, aquatic functional group species, including southern bristle-sedge *Chorizandra australis*, fine twig-sedge *Machaerina arthropphylla* and the square twig-sedge *Machaerina tetragona* dropped in frequency after 2017 and have not yet returned to pre-2017 levels. The exception to this appears to be the common water-ribbons *Cychnogeton procerum* sp. aff. which increased in

frequency in 3 sites and appears to respond quickly to changes in available water and tends to increase in frequency after yearly rainfall increases.

As with the 2021 surveys, it appears that several dominant species have died back in recent years. This has occurred for the square twig-sedge at site AS2 and the fine twig-sedge, the tall rush and the spreading rope-rush at site AGP2_2014. The timing and cause of this die-back remains unclear. It is understood that these sites were dry in 2014 and were either dry or had only 3 cm of standing water recorded in only 2 quadrats in 2015 (Ecology Australia 2014, Ecology Australia 2015). Using the photo point data from 2014, neither site had the same extent of clearly dead vegetation in 2014 or 2015 with AGP2_2014 showing many healthy flowering stems of tall rush. In the dominant species frequency data for AGP2_2014, the frequency of tall rush and the fine-twig sedge remain relatively stable until 2017 after which their frequency drops significantly. Similarly at AS2, the dominant square twig-sedge shows a drop in frequency after 2017. Both twig-sedges fit within the Aquatic functional group, which are most susceptible to changes in hydrology and not tolerant of long periods without water. The tall rush fits within the Amphibious fluctuation tolerator–emergent functional group which have more tolerance to changing water levels but require 8–12 months of the year to have water present. It is likely that the dry conditions of 2014 and 2015 initiated the die-back of these species, however there are other variables that can affect plant health such as soil and water salinity and acidity. Both the tall rush and the square twig-sedge appeared to show signs of recovery in 2021 with both species increasing in frequency at their respective sites, however this was not obvious in the field. Dead thickets had one or two resprouting live stems which allowed them to be scored as present despite the majority of the individual or stand being dead. This means while each species is still present and increasing in frequency, it clearly hasn't yet recovered to pre-die-off levels.

Algal mats have increased in 2 sites in the Anglesea Swamp (first recorded in 2016) from 2021. While algae are a normal part of wetland ecosystems, the growth of algae can also be associated with low flows (Mitrovic and Bowling 2013, Davie and Mitrovic 2014) and might suggest reduction of overbank flows in the swamp. At this stage, there are no obvious impacts on the vegetation.

4.1.1 Botanical recommendations

Recommendations regarding the vegetation monitoring component include:

- Addition of cover estimates of species in each quadrat along a transect following the Braun Blanquet cover abundance scale. Cover estimates allow trends to be detected at a finer scale compared to presence and absence scores alone. This will allow the MAP to detect changes in vegetation before species decline significantly and be able to track the trajectory of species which appear to have significantly declined in sites AS1 and AGP2_2014.
- Consider as part of the Bulk Entitlement review process using GIS to analyse and detect large scale changes in vegetation across the Anglesea swamp and estuary. This could be approached by analysing the percentage cover and change over time of the dominant Swamp Scrub EVC and Aquatic Sedgeland EVC (or representative dominant species). Dominant components of each EVC or key species could be differentiated using colour (aerial, satellite or drone), reflectance properties of vegetation (satellite) or heights using LIDAR. This may allow changes in extent of dominant species such as the scented paperbark *Melaleuca squarrosa* to be detected at the scale of the whole swamp. This was attempted this year across selected Anglesea Monitoring sites however, the differences in resolution and colour of available imagery provided

unmeaningful results. Despite this, the method used was successful enough at identifying vegetation types and it is believed that with appropriate imagery, this could be a valuable tool to detect largescale changes in vegetation.

4.2 Frogs

The 2022 frog surveys completed as part of the Anglesea MAP were broadly consistent with those of previous years. However, there was an increase in abundance of the three frog species occurring within the Anglesea Swamp over the two survey events (Table 4, Figure 7). This increase in abundance appeared to have corresponded with the increase in rainfall recorded for the year. Conversely, there was a reduction in the numbers and diversity of frog species recorded at the Anglesea Estuary (Table 5, Figure 7).

Frogs were typically heard within 100 m of Anglesea swamp sites during at least one of the surveys, with the exception of AS4 where no frog species were heard calling within 100 m. Similarly, southern brown tree frog were not detected within 100 m of AS6 and ASP7, while pobblebonk were not detected within 100 m of AS6. Conversely, across the 4 estuary sites, frogs were typically heard calling from distances of greater than 100 m away (Table 5), with southern brown tree frogs the only frog species detected calling within 100 m of site LAR1, suggesting that frogs tended to be present within the wider estuary area. The increased diversity and abundance relative to previous years, with the exception of 2016 at the Anglesea swamp appears related to the increase in habitat and quality across these sites.

The persistence of frog populations at a site depends on the ability for individual species to produce viable offspring that, in turn, have the ability to reproduce and contribute to the subsequent generation of individuals. As such, there is an obvious need for adequate aquatic habitat at each site for breeding purposes, with adequate water depth being a primary determinant of successful breeding in frogs. Although the timing of water availability may differ between species, adequate water must be present for an adequate period for larvae to undergo development and achieve metamorphosis; whereby they are less dependent on free-standing water. Moreover, while all 3 frog species (common froglet, southern bullfrog and southern brown tree-frog) have extensive breeding seasons, the period required for metamorphosis is more variable. Southern bullfrog tadpoles metamorphose from December to April and require 3–6 months to metamorphose. Conversely, common froglet tadpoles may metamorphose in as little 4–6 weeks and are tolerant of small, highly intermittent waterbodies with unstable conditions, making this species less susceptible to water level changes and the drying-out of water bodies (Lane and Mahony 2002, Hazell et al. 2003, Anstis 2013). As such, for southern bullfrog to achieve successful metamorphosis at a site, and hence maintain all three species at a site likely requires free-standing water for over 6 months (Anstis 2013).

During the 2022 surveys, water levels and associated water quality parameters remained relatively constant and suitable for frogs across all Anglesea Swamp sites and frog diversity and abundance (as indicated by frog call behaviour) remained consistent among surveys and sites at the Anglesea Swamp. Conversely, among the Anglesea estuary sites, water levels and water quality parameters remained relatively ideal, with the exception of salinity among both surveys. In past years, a combination of water availability and associated water quality, resulting from changes in water level were suggested for the observed differences in frog abundance and diversity. In the 2022 survey there appears to be no such clear biophysical descriptor relating to frog abundance and diversity, particularly among estuary sites.

Most importantly, the number of frogs heard calling at the estuary site was the lowest since 2019, suggesting that frog diversity at the estuary sites may be more variable, despite having relatively constant water quality conditions, than the Anglesea swamp sites. A likely explanation for the absence of frogs (frogs were calling nearby >100 m away) at the Anglesea Estuary being that the increase in availability of suitable free-standing water surrounding the Anglesea Estuary. As such, it is possible that frogs located around the estuary had access to an increased range of suitable free-standing water, which may have caused them to move away from the survey sites located along the estuary. The ability to disperse and move being a key adaptive strategy among many south-east Australian frog species in response to climate variability and change (Wassens et al. 2013).

In summary, the presence and detection of frogs is closely linked to the weather conditions preceding the survey events. Climatic variability and annual variation in rainfall can cause frogs to move within the landscape. As such, frogs may move considerable distances in response to changes in water availability. In the case of frogs located at the Anglesea Estuary this may have resulted in frogs being located away from the sites examined as part of this study, as such the estuary sites may be more variable than those of the Anglesea Swamp.

4.3 Aquatic ecology

The macroinvertebrate monitoring results were relatively consistent with the previous 3 years (Ecology Australia 2020–22), with a slight improvement evident in the present year compared with the previous three. The overall trend for the macroinvertebrate assemblage for the study area as shown at the Breakfast Creek tributary and Salt Creek sites has been decline since at least 2014, in particular for the Breakfast Creek tributary site. Due to the new index (VLAKES) used for the wetland site this year in addition to the inconsistency with which wetland site(s) have been surveyed (wetland 2/3 combined during annual, wetland 2 and wetland 3 during triennial and wetland 1 annually prior to 2017), we did not plot the macroinvertebrate assemblage trajectory through time. The inconsistency of sites surveyed should be resolved during the next MAP review and trajectory at wetland sites tracked through time. Attainment of ERS objectives remains low with SIGNAL2 (creek sites) and VLAKES (wetland site) being the only categories meeting relevant objectives. The extreme low pH conditions within the sites are the most obvious explanation for the depauperate macroinvertebrate assemblage with low pH having been shown to have a negative effect on macroinvertebrate diversity (e.g. Courtney and Clements 1998, Tripole et al. 2008).

Southern pygmy perch CPUE at site SC1 was broadly comparable with the last 5 years. Salt Creek CPUE was expected to be relatively low during the 2022 survey due to higher flows and the corresponding dilution effect this has on fish densities and capture rates, although even higher flows were encountered in 2021. There were no young-of-year fish detected during 2022 (with the majority of the fish >40 mm TL), which is the first failure to detect young-of-year individuals since 2019 and is indicative of recruitment failure (either failure to spawn or mortality of eggs/larvae or early juveniles). The reasons for this are unknown but could include the sustained increased flow conditions in 2021 with southern pygmy perch benefiting from stable spring/summer conditions. Fish colouration (in breeding colours) and the presence of ripe fish is a good sign that the southern pygmy perch within Salt Creek were in good condition and that spawning activity was occurring or was imminent at the time of survey.

No southern pygmy perch have been detected at BCT1 since 2017. This result potentially provides a strong indication of local extirpation of the southern pygmy perch population formerly located in the

vicinity of site BCT1. This population has previously ‘reappeared’ after several years of no detection or recruitment (GHD 2013–2015), suggesting that more favourable and permanent habitat (i.e. a ‘source population’) may be located somewhere nearby. However, 5 years of non-detection including multiple wetter years with periods of connectivity for dispersal and recolonisation is a bad sign for population recovery. We recommend additional effort occur to determine the ongoing existence of the southern pygmy perch in the Breakfast Creek catchment and the proximity of any new sites to the existing monitoring site. Given the population of southern pygmy perch in the Anglesea catchment is genetically distinct (Cesar 2012), it is likely to be important to maintain populations within both Salt Creek and Breakfast Creek. Identification and monitoring of source population sites should, therefore, form an important component of the monitoring program for future years.

Otway bush yabby abundances appeared to be considerably higher in 2022 compared with 2021 (although not quite at the high abundances of 2020). During the present project year, an attempt was made to track the trajectory of this species over time, however due to the inconsistent collection of data (i.e. considered a non-target by-catch species previously) and the misidentification of this species prior to 2017, this was not possible. However, this analysis did show that bait traps alone are not a sufficient method to monitor for this species. For example, in 2022 at Salt Creek no Otway bush yabby were captured in the bait traps but this species was present at the site as shown by the sweep netting. This was likely due to the habitat targeted by these methods with sweep netting targeting more suitable habitat (i.e. littoral habitat) for this species during the wet year in Salt Creek than the bait trapping (i.e. deeper habitat). We therefore suggest that all Otway bush yabbies captured be recorded (measured, weighed, counted as appropriate) regardless of the method used, i.e. by both bait trap and sweep net per replicate. All sites where Otway bush yabby were detected in 2022 were again flowing and suitable habitat was abundant in the littoral areas. During 2022, young-of-year and juvenile individuals were detected in 2022 in good abundance at Breakfast Creek, indicating this species is continuing to recruit well within Breakfast Creek. This species can complete its life cycle in both permanent and more intermittent habitats and the 2021–2022 wetter conditions are providing this species with dispersal opportunities, which may lead to larger and more widespread populations in future years. Low pH levels (< 3.5), particularly within the lower Anglesea River wetlands, may inhibit the spread of Otway bush yabby within the Anglesea catchment, however the species has been detected in areas of lower pH in 2022 (2.8 in Breakfast Creek) and previously (4.85 in 2021 and 4.2 in 2020) (Ecology Australia 2020–2021), hinting that the Anglesea catchment population may be tolerant of or adapting to lower pH conditions.

4.3.1 Aquatic ecology recommendations

Recommendations regarding the aquatic monitoring component were proposed after the 2018 monitoring event (Ecology Australia 2019). These recommendations remain current and are reproduced and expanded upon below:

- The monitoring design should be reviewed and refined as part of the review of the MAP. For example, it is unusual to collect 3 RBA samples per site for a compliance monitoring program, when objective attainment can be assessed using a single edge sample (in the absence of a riffle sample). Additionally, one site (Wetland 2/3) typically has too small an area of available habitat to collect 3 edge samples without potentially reducing the quality of all 3 samples collected (e.g. overlapping areas of habitat sampled). This is shown in the present year with the first edge sample collected at wetland 2/3 (i.e. targeting the ‘best’ habitat with no

overlap) being the most diverse and abundant and subsequent samples producing a lesser result. Although collection of additional samples in monitoring programs is typically recommended for data analyses benefits (e.g. higher statistical power), RBA samples are not qualitative samples, and much more than three samples per site would be required to account for the large amount of variability. The cost savings associated with this change would be better directed towards enhancing the monitoring of southern pygmy perch and Otway bush yabby populations.

- We also suggest that the review better define wetland 2/3 as this site is surveyed inconsistently between the annual and triennial survey years, i.e. combined in the annual survey and separated during the triennial survey since the annual surveys were relocated to wetland 2/3 from wetland 1. Given the very close proximity and lack of independence (wetlands 2 and 3 are only separated by a road with a connecting culvert crossing underneath), our suggestion is to permanently combine this site and re-define collectively as 'wetland 2'.
- Given that it has been 5 years since southern pygmy perch have been detected at BCT1, it would be beneficial to survey additional/alternative locations on Breakfast Creek to establish if a population persists in the area. At a minimum, we suggest including bait trapping at all Breakfast Creek sites during future triennial macroinvertebrate surveys (i.e. when additional sites on Breakfast Creek are surveyed for macroinvertebrates). Ideally, a one-off broader survey of the catchment would be undertaken including known refuge pools in the Breakfast Creek, Salt Creek and Anglesea River catchments (as identified in GHD 2010), supplemented by eDNA at other locations. As a genetically distinct population in an isolated catchment (Cesar 2012), it is of concern that local extirpation of the Breakfast Creek population may have occurred, that the current status of the species in the catchment is unknown, and that only one site is being monitored as part of this monitoring program. The broader survey would ideally be undertaken in late summer/autumn in terms of maximising capture rates (traditional methods) and minimising dilution rates (eDNA).
- Otway bush yabby has been an informal target species of the monitoring program since 2019. Although monitoring of this species has yielded more promising results than for southern pygmy perch in recent years, knowledge of the distribution and demographics of the broader population is still limited. It is recommended that Otway bush yabby be formally recognised as a target species in the next MAP. As the survey methods for southern pygmy perch is also suitable for Otway bush yabby (i.e. bait traps), we recommend that this be cost effectively piggy-backed on the expanded ongoing and one-off southern pygmy perch monitoring that is detailed above.
 - Collection of data from 2022 onwards should be consistent with the approach used in 2022, i.e. all Otway bush yabby should be recorded (measured, weighed, counted as appropriate) for both bait trapping and sweep netting.
 - Tracking population change over time for Otway bush yabby should occur when sufficient comparable data for this species is available.

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Appendix 1 Anglesea Borefield, terrestrial ecology, Monitoring and Assessment Program, Anglesea Swamp, native plant species and Functional Groups (native plant species only) spring 2022.

Status	Scientific name	Common name	FG	AGP2_2014	AS1_2014	AS2	AS3	AS4	ASP7_2014
	<i>Banksia marginata</i>	silver banksia	Tdr			x			
	<i>Cassytha glabella</i>	slender dodder-laurel	Tdr				X	X	X
	<i>Cassytha pubescens</i>	downy dodder-laurel	Tdr			X			
	<i>Chorizandra australis</i>	southern bristle-sedge	Se			X			
	<i>Cycnogeton procerum</i> sp. aff.	common water-ribbons	Se	X	X	X		X	X
	<i>Drosera binata</i>	forked sundew	Tda				X		
	<i>Empodisma minus</i>	spreading rope-rush	Ate		X		X	X	X
P	<i>Epacris obtusifolia</i>	blunt-leaf heath	Atw				X	X	X
vu	<i>Eucalyptus falciformis</i>	western peppermint	Tdr			X			
	<i>Gahnia radula</i>	thatch saw-sedge	Tdr			X			
	<i>Gahnia sieberiana</i>	red-fruit saw-sedge	Ate	X				X	X
P	<i>Gleichenia dicarpa</i>	pouched coral-fern	Ate		X		X	X	X
P	<i>Gleichenia microphylla</i>	scrambling coral-fern	Ate				X	X	
	<i>Isolepis inundata</i>	swamp club-sedge	Ati	X	X				
	<i>Juncus procerus</i>	tall rush	Ate	X					
	<i>Lepidosperma longitudinale</i>	pithy sword-sedge	Ate					X	X
	<i>Leptospermum lanigerum</i>	woolly tea-tree	Atw						X
	<i>Leptospermum</i> spp.	tea-tree	T	X	X	X	X	X	X
	<i>Machaerina arthropophylla</i>	fine twig-sedge	Se	X	X			X	X
	<i>Machaerina juncea</i>	bare twig-sedge	Ate		X				X
	<i>Machaerina tetragona</i>	square twig-sedge	Se			X	X		
P	<i>Melaleuca squarrosa</i>	scented paperbark	Atw	X	X	X	X	X	X
	<i>Opercularia varia</i>	variable stinkweed	Tdr			X			
	<i>Platylobium obtusangulum</i>	common flat-pea	Tdr			X			

Status	Scientific name	Common name	FG	AGP2_2014	AS1_2014	AS2	AS3	AS4	ASP7_2014
	<i>Pteridium esculentum</i> subsp. <i>esculentum</i>	austral bracken	Tdr		X	X			
	<i>Rhytidosporum procumbens</i>	white marianth	Tdr			X			
	<i>Schoenus brevifolius</i>	zig-zag bog-sedge	Atw		X	X	X	X	X
P	<i>Sprengelia incarnata</i>	pink swamp-heath	Ate				X	X	
	<i>Thelymitra</i> sp.	sun-orchid	Tdr			X			
	<i>Xyris operculata</i>	tall yellow-eye	Ate				X		
Number of species per site				7	10	15	12	13	13
Total number of species				30					

Appendix 2 Anglesea Borefield, terrestrial ecology, Monitoring and Assessment Program,
Anglesea Estuary, plant species and Functional Groups spring 2022.

Status	Scientific name	Common name	Functional group	LAR1	LAR2	LAR3	LAR4
# P	<i>Acacia longifolia</i> subsp. <i>longifolia</i>	sallow wattle	NA			X	
# P	<i>Acacia longifolia</i> subsp. <i>sophorae</i>	coast wattle	NA	X			
	<i>Cycnogeton procerum</i> sp. aff.	common water-ribbons	Se	X	X	X	X
	<i>Eucalyptus ovata</i> subsp. <i>ovata</i>	swamp gum	Tda	X		X	
	<i>Ficinia nodosa</i>	knobby club-sedge	Tdr			X	
	<i>Gahnia sieberiana</i>	red-fruit saw-sedge	Ate	X			
*	<i>Gladiolus</i> spp.	gladiolus	NA		X		
	<i>Goodenia ovata</i>	hop goodenia	Tdr	X	X	X	
	<i>Goodenia radicans</i>	shiny swamp-mat	Arp		X	X	X
	<i>Isolepis inundata</i>	swamp club-sedge	Ati	X			
	<i>Juncus kraussii</i> subsp. <i>australiensis</i>	sea rush	Se	X	X	X	X
	<i>Lachnagrostis filiformis</i>	common blown-grass	Tdr		X		
	<i>Leptospermum</i> spp.	tea-tree	T	X	X	X	
	<i>Lobelia anceps</i>	angled lobelia	Ate	X	X	X	X
	<i>Myoporum insulare</i>	common boobialla	Tda		X		
	<i>Phragmites australis</i>	common reed	Arp		X	X	
	<i>Poa poiformis</i> var. <i>poiformis</i>	coast tussock-grass	Tdr		X	X	
P	<i>Senecio glomeratus</i>	annual fireweed	Tdr		X		
*	<i>Symphotrichum subulatum</i>	aster-weed	NA		X		
	<i>Typha domingensis</i>	narrow-leaf cumbungi	Se	X			
	<i>Rytidosperma</i> sp.	wallaby-grass	NA		X		
Number of species per site				10	14	11	4
Total number of species				21			

Appendix 3 Results by sample, including genus identifications where identified, for all macroinvertebrate sites sampled in 2022 (E1 = Edge sample 1, E2 = Edge sample 2 and E3 = Edge sample 3, T = Total per site).

Species		W2/3				BCT1				SC1			
Family	Genus	E1	E2	E3	T	E1	E2	E3	T	E1	E2	E3	T
<i>Acarina</i>	sp.							1	1				
<i>Chironominae</i>	sp.		7		7								
<i>Corixidae</i>	sp.	1			1								
<i>Culicidae</i>	sp.	6		2	8								
<i>Dytiscidae</i>	sp.	3		1	4		1		1	1	1	3	5
<i>Gripopterygidae</i>	<i>Illiesoperla</i>					13	13	23	49			1	1
<i>Hydrobiosidae</i>	<i>Taschorema</i> complex					1		1	2				
<i>Janiridae</i>	sp.	3			3						1		1
<i>Leptoceridae</i>	sp.*	2			2								
<i>Leptoceridae</i>	<i>Triplectides</i>					3	1	1	5		4		4
<i>Leptophlebiidae</i>	<i>Nousia</i>										1		1
<i>Nannochoristidae</i>	sp.					1		1	2		4	1	5
<i>Oligochaeta</i>	sp.										1		1
<i>Orthocladiinae</i>	sp.										1	2	3
<i>Paramelitidae</i>	sp.									3	4	8	15
<i>Polycentropodidae</i>	<i>Plectrocnemia</i>										1		1
<i>Scirtidae</i>	sp.	64	2	10	76	3	1		4	3			3
<i>Simuliidae</i>	sp.					2		9	11			4	4
<i>Talitridae</i>	sp.					1			1				
<i>Tanypodinae</i>	sp.					1		2	3		18	6	24
<i>Tipulidae</i>	sp.									1		1	2
<i>Veliidae</i>	sp.					1		1	2	4	3	5	12

*Specimens damaged and could not be identified to genus



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Anglesea Borefield Ecological Monitoring and Assessment Program 2021



Prepared for: Barwon Water

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Cover photo: Otway bush yabby released into Breakfast Creek during the 2021 fish surveys – Bryce Halliday

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- Scientific Procedures Fieldwork License 20097

Summary

Introduction

Barwon Water is permitted to extract groundwater from the Anglesea Borefield, under the Bulk Entitlement (Anglesea Groundwater) 2009 (BE), to supplement the water supply to Geelong and surrounding areas when required (Victorian Government 2009). The BE requires data to be collected to monitor the impacts of water drawdown under a Monitoring and Assessment Program (MAP) established in 2009.

Per the updated MAP (revised in 2014) (Victorian Government 2014), Ecology Australia was commissioned to undertake both the aquatic and terrestrial ecological monitoring in 2021. The 2021 aquatic ecological monitoring in 2021 included the triennial macroinvertebrate survey of 11 sites. The terrestrial monitoring, which is typically biennial and last conducted in 2020, was required again in 2021 as the borefield was operated in 2021, albeit in standby mode, triggering the requirement for the terrestrial monitoring. Ecology Australia has undertaken terrestrial monitoring (vegetation and frogs) since 2009 and aquatic monitoring since 2017.

Methods

Vegetation monitoring was undertaken along six permanent transects in the Anglesea Swamp and four permanent transects in the Anglesea Estuary. The data collected included:

- Plant species lists
- Ecological Vegetation Class (EVC)
- Plant Functional Group
- Bare ground cover
- Water depth (in the swamp only)

Frog survey data was collected at eight sites in the Anglesea Swamp and four sites in the Anglesea Estuary and included:

- Species richness
- Abundance
- Water quality
- Habitat attributes

Aquatic monitoring consisted of the one in three year spring macroinvertebrate surveys undertaken at 11 sites as well as targeted surveys for southern pygmy perch and Otway bush yabby at two sites. Fish and macroinvertebrate monitoring included:

- Taxonomic diversity (macroinvertebrates)
- Abundance
- Biometrics (fish and crayfish)
- Water quality
- Habitat attributes

Findings

Vegetation

Ecological Vegetation Classes and the number of plant species present in the wetland communities remain largely unchanged within the Anglesea Swamp and Estuary. Overall, frequency of the aquatic plant functional group has decreased across both the Anglesea Swamp and Anglesea Estuary since monitoring commenced. The average frequency of the amphibious functional groups has remained relatively consistent across the Anglesea Swamp and Anglesea Estuary. In the Anglesea Swamp, the dry functional group has remained the least frequent functional group in the swamp and have displayed a slightly decreasing trend across all monitoring years. However, in the Anglesea Estuary, the dry functional group is displaying a slight increasing trend across all monitoring years.

The number of sites containing algal mats has decreased from a maximum of five (2017 and 2019) to three sites (2020 and 2021). Despite this, two of the three sites display an increasing trend in the frequency of algal mats recorded across each site.

Frogs

Frogs were recorded from 3 of 8 sites at Anglesea Swamp within 100 m of the site and frogs were heard calling from more than 100 m away at 6 of the 8 sites in 2021. Southern brown tree frog, common froglet and southern bullfrog were all recorded within the Anglesea swamp. Frogs were recorded at all 4 of the Anglesea Estuary sites in 2021. Only southern brown tree frog and southern bullfrog were recorded within the Anglesea Estuary. All records in 2021 were from calling male frogs with none visually sighted. Results of the 2021 frog surveys show in general that the number of frogs heard calling at the estuarine sites are higher than all years except 2020. On the other hand, the swamp sites show an increase in frog numbers compared to 2019 and 2020. However, both sites show that there are different responses by different species each year.

Southern pygmy perch & Otway bush yabby

Southern pygmy perch were again only detected from one of the two monitoring sites, the Salt Creek site, which has been a consistent result for the past four years. Recruitment was again detected at the Salt Creek site and is the second year in a row where young-of-year and juvenile fish were detected. This year's sampling (2021) was the fourth consecutive year that southern pygmy perch were not recorded in the Breakfast Creek tributary. Based on this result, we suggest that this population may now be locally extirpated. It would be advisable to determine if there is a source population elsewhere in the Breakfast Creek catchment as a possible source of recolonisation into the Breakfast Creek tributary.

Otway bush yabby was detected at six of the 11 sites surveyed during the triennial macroinvertebrate survey including the Salt Creek and Breakfast Creek tributary sites where they have been detected annually since 2017 (Ecology Australia 2018–2021). Otway bush yabby abundance abundances were considerably lower in 2021 compared with 2020, although this may be due to the increased habitat available in 2021 due to the wet winter/spring. Small, young-of-year/juvenile, individuals were detected in 2021, indicating this species is continuing to recruit.

Macroinvertebrates

The macroinvertebrate monitoring results were relatively consistent with previous years and indices comparison against State Environmental Protection Policy – Waters objective (SEPP (W); Vic. Gov. 2018) was overall fairly poor. The Breakfast Creek and tributary sites appear to have marginally improved and the upper Anglesea River sites appear to have marginally declined (C.f. Ecology Australia 2019, 2021). Due to the very wet winter/spring in 2021 all 11 triennial macroinvertebrate survey sites had sufficient water to collect triplicate edge samples (only nine were sufficiently wet during the most recent triennial macroinvertebrate survey).

1 Introduction

Barwon Water is permitted to extract groundwater from the Anglesea Borefield, under the Bulk Entitlement (Anglesea Groundwater) 2009 (BE), to supplement the water supply to Geelong and surrounding areas when required (Victorian Government 2009). Groundwater pumping under the BE is permitted as long as it does not adversely affect environmental values and groundwater-dependent ecosystems in the Jan Juc Groundwater Management Area.

The BE requires data to be collected to monitor the impacts of water drawdown. At the commencement of the BE, a Monitoring and Assessment Program (MAP) was developed. The MAP has been revised and updated once, in September 2014 under the Bulk Entitlement (Anglesea Groundwater) 2014 (henceforth to be referred to as the “BE” succeeding the previous version; Victorian Government 2014). The MAP includes groundwater and surface water monitoring, acid sulphate investigations, land-level surveying and aquatic and terrestrial ecological monitoring (Victorian Government 2014).

Ecology Australia has undertaken the terrestrial (vegetation and frogs) monitoring component of the MAP since 2009 and the aquatic component (fish and macroinvertebrates) since 2017 (Ecology Australia 2009–2021).

The current MAP requires aquatic ecological monitoring to be undertaken annually (with an increased number of sites every three years), and terrestrial ecological monitoring to be undertaken biennially in the absence of groundwater pumping, and annually during periods of groundwater extraction (Victorian Government 2014). Barwon Water operated the borefield in stand-by maintenance mode during the 2020/21 financial year only extracting a very small volume of 13.5 ML (Barwon Water 2022). As borefield extraction occurred during 2021 (i.e. during this present reporting period) the MAP requirement for terrestrial ecological monitoring was triggered (this would not have been required in 2021 if the borefield was not operated).

The 2021 ecological monitoring includes the Aquatic Ecology and Terrestrial Ecology components as detailed below.

1.1 Aquatic Ecology

The Aquatic Ecological monitoring component included the one in three year spring monitoring of macroinvertebrates at 11 sites:

- Breakfast Creek (BC 1–3) tributary (BCT 1–2)
- Salt Creek (SC1)
- Lower Anglesea River wetland (Wetland 1–3)
- Upper Anglesea River (UAR1–2)

Additionally, this component included spring sampling of southern pygmy perch *Nannoperca australis* and Otway bush yabby *Geocherax tasmanicus* at two sites:

- Breakfast Creek tributary (BCT1)
- Salt Creek (SC1)

1.2 Terrestrial Ecology

The Terrestrial Ecological monitoring component included spring monitoring of vegetation along established transects at six sites and frog monitoring at eight sites in the Anglesea Swamp (Figure 1):

- AS1_2014 (vegetation and frog monitoring)
- AS2 (vegetation and frog monitoring)
- AS3 (vegetation and frog monitoring)
- AS4 (vegetation and frog monitoring)
- AS5 (frog monitoring only)
- AS6 (frog monitoring only)
- ASP7_2014 (vegetation and frog monitoring)
- AGP2_2014 (vegetation and frog monitoring).

Additionally, spring monitoring of vegetation was undertaken at established transects at four sites and frog monitoring was undertaken at the same sites in the Anglesea Estuary:

- LAR1
- LAR2
- LAR3
- LAR4.

Vegetation data collection included floristic species lists, Ecological Vegetation Classes (EVCs), plant Functional Groups, and other structural and physical attributes (water depth, bare ground and algal mats).

The frog monitoring data collection included species richness, abundance, water quality, and habitat attributes.

This report presents the monitoring methods and results, along with a discussion including a comparison of the 2020 data with annual data collected since the MAP review and update in 2014.

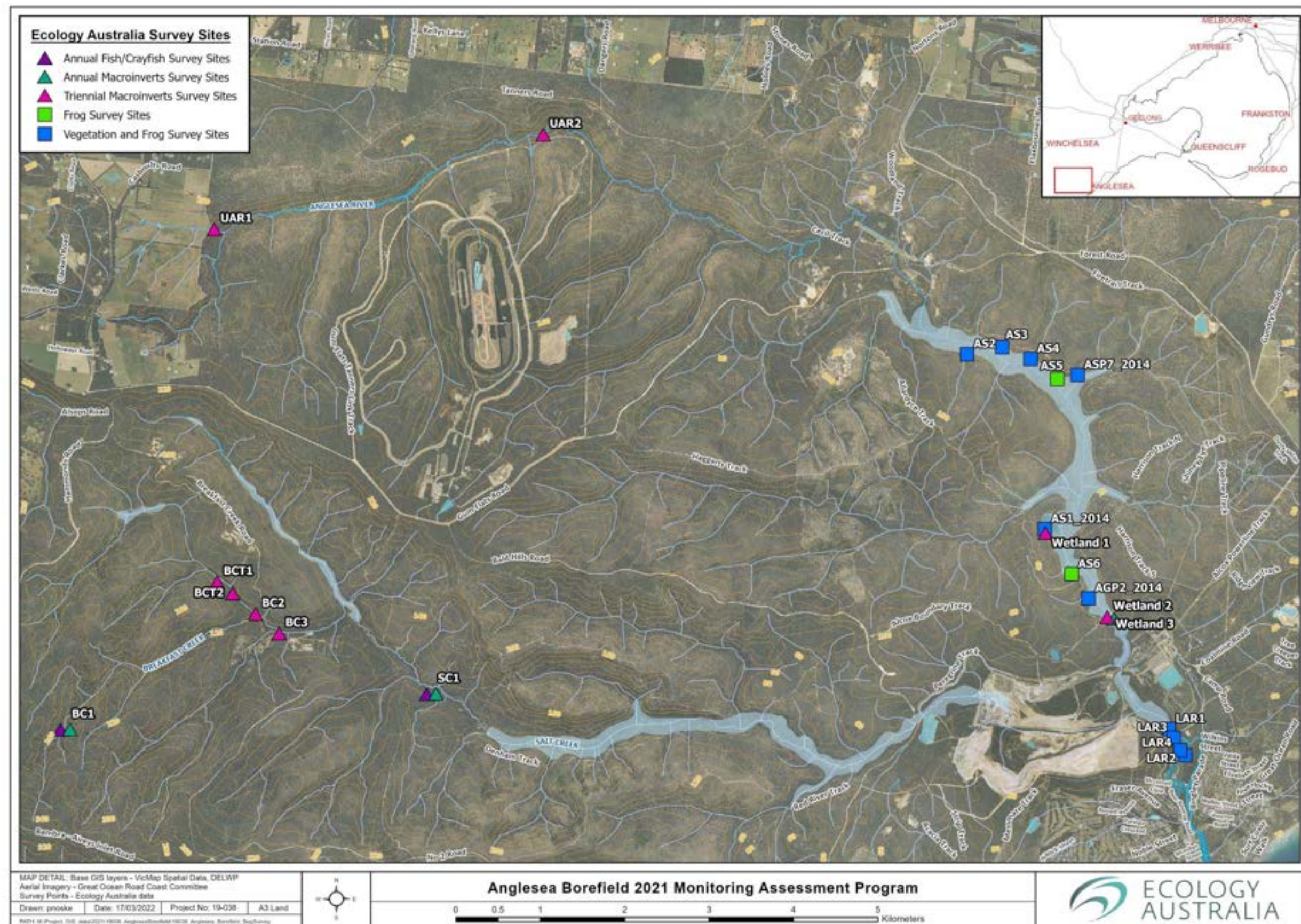


Figure 1 Anglesea Borefield Ecological Monitoring and Assessment Program survey sites 2021

2 Methods

2.1 Vegetation

In the last week of October 2021, vegetation monitoring was conducted at the following sites in the Anglesea Swamp: AS1_2014, AS2, AS3, AS4, ASP7_2014 and, AGP2_2014; and the following sites in the Anglesea Estuary: LAR1, LAR2, LAR3, and LAR4.

2.1.1 Data collection

One established transect was surveyed at each site. Along each transect, 1 m² quadrats are located every second meter along the left-hand side of the transect looking start to end, with the first quadrat placed at 1-2 m, the second placed at 3-4 m and so on. There are 50 quadrats along each transect in the swamp, 15 quadrats along LAR2, LAR3 and LAR4 transects and 7 quadrats along LAR1 in the estuary. Field staff walk on the right-hand side of the transect to avoid trampling vegetation within the quadrats.

Survey methods collect the presence/ absence of vegetation species within quadrats located along transects to produce a frequency score for each species. Species abundance in each quadrat is determined by recording the presence of each species that have live plants rooted in or overhanging each cell.

Additionally at each quadrat, EVCs following the Department of Environment, Land, Water and Planning (DELWP) benchmarks (DELWP 2022a) were recorded, as well as other attributes including water depth (in the swamp only) and percentage cover of bare ground, rounded to the nearest 5% and presence of algal mat. Photo points are taken at each site and are located at 0 m, 25 m, 50 m, and 75 m along each transect in the swamp and the start of each transect in the estuary. Photos were taken looking toward the end of the transect.

Water depth is a snapshot in time (one day of the year) and will vary considerably over time depending on rainfall. Hydroperiod is a fundamental driver of wetland condition (e.g. Foti et al. 2012).

Bare ground provides space for plant recruitment. This can indicate potential change at a site, for example — are the extant Functional Groups (FGs) recruiting, or are conditions favouring the recruitment of drier or wetter groups?

Plant functional groups

Plant species recorded in surveys across the Anglesea Swamp and Anglesea Estuary were classified into functional groups (FGs) (Table 1). Functional groups are based on the ecology (known or likely water requirements) of plant species, modified from Cassanova (2011) and Doeg et.al. (2012), as detailed in Ecology Australia (2013b). Functional group T (instead of Tdr or Tda) and A (instead of Ate, Atl, Atw or Arp) were assigned where species were identified to genus or family level only.

2.1.2 Data analysis

Species composition

Species richness was presented in a table form displaying total number of native species and number of plants per broad functional group. Additionally, species richness was presented in a bar chart form for each site across each monitoring period.

To analyse species composition across monitoring seasons, the average percentage frequency of each species across all sites was calculated for each monitoring season for both the Anglesea Swamp and Anglesea Estuary. Species composition (species richness and abundance) was then analysed through an ordination using non-metric multidimensional scaling (NMDS). Vectors were fitted for species that significantly contributed to the community composition differentiation between years.

Plant functional groups

Plant functional groups were used to assess the changes in ground water dependant vegetation across the swamp and estuary.

For both the Anglesea Swamp and Anglesea Estuary, the average percentage frequency of broad functional groups: Amphibious (Atw, Ate, Atl, Arp), Aquatic (Se) and Dry (T, Tdr, Tda) across all sites for each monitoring period was presented in a bar chart form along with average rainfall.

At an individual site level, the average percentage frequency of broad functional groups was presented in a bar chart form for all monitoring years. The top three dominant species for each site were presented as a line chart as the percentage frequency across all monitoring years. For any given year, the dominant three species were displayed, therefore sites with fluctuating dominant species across the years may display more than three species.

Algal mats

The presence of algal mats was presented in a bar chart form as the percentage frequency of algal mat at each site across all monitoring years.

Table 1 Anglesea Borefield, ecological Monitoring and Assessment Program, Plant Functional Groups (modified from Cassanova 2011 and Doeg et.al. 2012)

FG	Definition	Example species
Dry		
Tdr	<i>Terrestrial dry</i> . This species group does not require flooding and will persist in damper parts of the landscape because of localised high rainfall. Species in this group can invade or persist in riparian zones and the edges of wetlands but are essentially terrestrial.	Messmate, Brown Stringybark, Prickly Moses, Silver Banksia
Tda	<i>Terrestrial damp</i> . These species germinate and establish on saturated or damp ground but cannot tolerate flooding in the vegetative state. They require the soil profile to remain damp for at least several months.	Swamp Gum, Variable Sword-sedge, Manuka, Slender Bog-sedge
Amphibious		
Atl	<i>Amphibious fluctuation tolerator - low-growing</i> . This species group can germinate either on saturated soil or under water and grow submerged, as long as they are exposed to air by the time they start to flower and set seed. They require or tolerate shallow flooding for approximately 3 months.	Austral Brookline, Swamp Club-sedge, Spotted Knotweed
Ate	<i>Amphibious fluctuation tolerator - emergent</i> . This species group consists of emergent monocots and dicots that survive in saturated soil or shallow water but require most of their photosynthetic parts to remain above the water (emergent). They tolerate fluctuations in the depth of water, as well as water presence. They need water or soil moisture to be present for 8–12 months of the year.	Tall Sedge, Red Fruit Saw-sedge, Pouched Coral-fern, Scrambling Coral-fern
Atw	<i>Amphibious fluctuation tolerator- woody</i> . This species group consists of woody perennial species that may hold their fruits (and seeds) in the canopy and require water to be present in the root zone all year round but will germinate in shallow water or on a drying substrate.	Woolly Tea-tree, Scented Paperbark
Arp	<i>Amphibious fluctuation responder - plastic</i> . This species group occupies a similar zone to the ATI group, except that they have a morphological response to water level changes such as rapid shoot elongation or a change in leaf form. They can persist on damp and drying soil because of their morphological flexibility but can flower even if the site does not dry out. They occupy a slightly deeper/wet-for-longer site than the ATI group.	Creeping Cotula, Monkey Flower, River Buttercup
Aquatic		
Se	<i>Perennial-emergent</i> . This category refers to monocotyledonous species that require permanent water in the root zone but remain emergent. They occur where water levels do not fluctuate or fluctuate with a relatively little drawdown in the dry part of the year.	Cumbungi, Sea Rush, Southern Water-ribbons

2.2 Frogs

Zoologists undertook two repeat surveys for frogs at 12 sites, on 17–18/11/2021 and 21–22/12/2021 (Figure 1):

- AS1_2014, AS2, AS3, AS4, AS5, AS6, ASP7_2014 and AGP2_2014 in the Anglesea Swamp
- LAR1, LAR2, LAR3 and LAR4 in the Anglesea Estuary.

Survey sites comprise the ten sites required by the MAP, as well as two additional sites (AS5 and AS6), which are surveyed if very low frog activity is observed in the Anglesea Swamp. In addition to the surveys undertaken by Ecology Australia, the local community provided information of frog calling from the greater Anglesea area.

2.2.1 Habitat assessment and water quality

To supplement the habitat data collected as part of vegetation monitoring, the following frog habitat variables were recorded:

- Wetland permanence (i.e. ephemeral, semi-permanent or permanent)
- Water quality parameters:
 - Temperature (° C)
 - pH
 - Electrical Conductivity (EC) (mS/cm)
 - Dissolved Oxygen (DO) (mg/L)
 - Turbidity (NTU).
- A general habitat description, including cover of fringing, emergent, submergent and floating vegetation.

Photos were also taken showing representative frog habitats at each survey site.

2.2.2 Frog surveys

Zoologists used both diurnal and nocturnal visual surveys to detect frogs at the survey sites. Nocturnal surveys also included call playback and spotlighting. Weather conditions at the time of the survey were recorded using a Kestrel weather meter. In 2021, all frog sampling events were completed during suitable weather in spring.

Visual surveys

Visual and aural surveys were undertaken at each site during the diurnal habitat assessment and at the beginning of each nocturnal survey. Surveys comprised two zoologists listening for approximately five minutes for the distinctive calls of male frogs. The species heard, and an estimation of the number of frogs calling for each species was recorded. In addition, zoologists looked for frogs at each site, by traversing the sites and scanning vegetation and the water surface for the presence of frogs. Visual nocturnal surveys were aided by the use of head-torches and/or hand-held spotlights, to look for the distinctive eye-shine of frogs.

Nocturnal call playback

Call playback was used following the nocturnal aural survey to elicit calling behaviour by male frogs that were not calling independently onsite. This approach uses the broadcast of pre-recorded calls of each species through a speaker, followed by a period of quiet listening. Frog calls broadcast during call playback, based on previous records included:

- southern brown tree frog *Litoria ewingii*
- southern bullfrog *Limnodynastes dumerilii*
- spotted marsh frog *Limnodynastes tasmaniensis*
- striped marsh frog *Limnodynastes peronii*
- common spadefoot toad *Neobatrachus sudellae*
- Victorian smooth froglet *Geocrinia Victoriana*
- common froglet *Crinia signifera*.

Call response data were used to estimate frog species richness and abundance within each site across the Anglesea catchment and estuary.

2.3 Aquatic ecology

2.3.1 Macroinvertebrate surveys

Macroinvertebrate surveys were undertaken at 11 sites between 28 October and 30 November 2021. As per the established methods (GHD 2016), triplicate edge samples were collected at each site where sufficient surface water was present, following the methods outlined in the Victorian Rapid Bioassessment (RBA) Methodology for Rivers and Streams (EPA 2003). A 250 µm mesh net with a 30 cm x 30 cm opening was used to collect each sample. Edge ('sweep') samples were collected from water bodies with little to no flow. The sampling objective was to subsample all types of habitats present, which can include overhanging vegetation, coarse woody debris, backwaters, bare edges, leaf packs and macrophytes. Each sample was collected from 10 m of habitat, which was not necessarily contiguous. The water column and habitats present were agitated to dislodge macroinvertebrates, suspend them within the water column and collect them within the net.

Samples were live-sorted ('picked') following the standard RBA procedures and preserved in 70% ethanol. In summary, the procedures entail:

- Picking for 30 minutes from a white tray, aiming to collect 200 animals from as many different taxa as possible
- If less than 200 animals are collected within 30 minutes, then picking continues for an additional 10 minutes
- If 200 animals are collected within 40 minutes and no new taxa are detected, then picking ceases; otherwise picking continues for an additional 10 minutes. This continues until a maximum of 60 minutes of picking has been completed
- Picking a maximum of approximately 30 of each taxa, except for groups that typically require microscopic examination to identify to the taxonomic resolution of family (e.g. Amphipoda) or

taxa which are to be identified to a lower taxonomic resolution than family (e.g. Chironomidae, Odonata, Ephemeroptera, Plectoptera and Trichoptera).

At each site, RBA field sampling and habitat assessment sheets were completed, including in situ water quality measurements using a calibrated Horiba U-52 water quality meter.

Since the detection of Otway bush yabby in 2017, this species has been monitored concurrently with fish and macroinvertebrates (Ecology Australia 2018–2021).

2.3.2 Macroinvertebrate identification

Macroinvertebrates were identified and enumerated with a stereo microscope using keys outlined in MDFRC (2013), which provides an update on those outlined in Hawking (2000). The majority of taxa were identified to family level, with the following exceptions as per the RBA protocols (EPA 2003):

- Chironomidae are identified to sub-family
- Oligochaeta and acarina are not identified below these taxonomic levels
- Adult and larval beetles are listed separately
- Terrestrial, semi-terrestrial and microcrustacean taxa were excluded
- Specimens of the orders ephemeroptera, plecoptera, trichoptera and odonata were identified to genus level, as per GHD (2016).

2.3.3 Macroinvertebrate data analyses

Macroinvertebrate data were analysed both at individual sample and site scale (using the combined data from three samples). Where available, the results were compared against indices objectives outlined in State Environment Protection Policy – Waters (SEPP(W); Victorian Government Gazette 2018) for surface waters in the Central Foothills and Coastal Plains geographic region. Where there is no relevant index available in the SEPP (W), the results were compared against the indices objectives used in previous reports.

The following indices were used to analyse macroinvertebrate data:

- Number of taxa — total number of taxa based on taxonomic resolution levels described above
- SIGNAL2 score — average SIGNAL score for taxa collected in each sample, based on methods of Chessman (2003). Table 2 provides the corresponding water quality categories.
- Number of EPT taxa — number of taxa from the orders of ephemeroptera, plecoptera and trichoptera (EPT). These taxa are typically considered more sensitive to pollution and disturbance and hence the index is an indicator of ecosystem health and
- Number of EPTO taxa — number of taxa from the orders of ephemeroptera, plecoptera, trichoptera and odonata (EPTO). This modified version of the EPT index is used for waterways in 'Mediterranean climate' regions, and aid in interpreting the health of lentic (still water) systems, where the numbers of plecoptera are diminished, while Odonata, which are also relatively sensitive to pollutants and disturbance, are more abundant and diverse (Pinto et al. 2004).

Table 2 SIGNAL score classifications (Chessman 1995)

SIGNAL score	Water quality
>7	Excellent
6-7	Clean water
5-6	Mild pollution
4-5	Moderate pollution
<4	Severe pollution

2.3.4 Fish surveys

Surveys targeting southern pygmy perch *Nannoperca australis* and Otway bush yabby *Geocharax tasmanicus* were undertaken at two sites: BCT1 and SC1 on 9 and 16 November 2021, respectively. For consistency with previous surveys, the BCT1 fish site was again relocated downstream.

Ten bait traps (stretched mesh size of 2 mm and funnel entrances of 40 mm diameter) with 100 mm long yellow glow sticks placed inside to serve as an attractant, were set in the afternoon and retrieved the following morning at both sites. This is consistent with the monitoring approach used in recent years (Ecology Australia 2018–2021).

The first 30 southern pygmy perch captured at each site were measured (total length) to the nearest millimetre and weighed to the nearest 0.1 gram. All remaining southern pygmy perch were counted.

All captures of Otway bush yabby were recorded per gear replicate (with individuals captured both within the bait traps and within sweep samples). All Otway bush yabbies captured using sweep samples were returned to the point of capture before macroinvertebrate samples were live-picked as described above (see: Section 2.3.1).

Instream habitat assessment was undertaken at all sites surveyed. The habitat assessment included notes on existing sources of disturbance, notes and estimates of biological and physical attributes (e.g. wetted instream cover, riparian shading, aquatic vegetation, substrate composition, flow and depth) and in situ water quality measurement. An outline of some of these habitat descriptors is provided below:

- The percentage cover of various forms of instream habitat (based on the proportion of the wetted area that they covered at the time of assessment).
- The shading estimate as per the EPA Rapid Bioassessment method (EPA 2003). This is an estimate based on a plan view as it would appear with the sun directly overhead (i.e. midday).
- The flow status estimate as per the USEPA field sheets that are incorporated into later iterations of the Victorian EPA Rapid Bioassessment field sheets (e.g. Version: September 2012). This is an estimate based on the proportion of the channel filled and/or substrate exposed.
- The disturbance rating estimate is based on the identification of several disturbance sources including levels of bank erosion, riparian vegetation clearance, parallel or adjacent roads, bridges/culverts/fords, rubbish, drain input, water extraction points, stock access, sedimentation, invasive exotic vegetation, barriers to fish passage, channelization and

hydrological alterations; together with a severity rating (i.e. high, medium, low) applied to the disturbance sources that were identified at a given site.

Water quality measurements (dissolved oxygen (mg/L), pH, temperature (°C), conductivity (mS/cm) and turbidity (NTU)) were made with a calibrated Horiba U-52 water quality meter.

2.4 Conservation status

Threatened species of state and/or national conservation significance were determined by reference to listings under the Victorian *Flora and Fauna Guarantee Act 1988* (FFG Act) and the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

Up until late 2021, Victoria maintained two threatened species lists including taxa listed under the FFG Act and the non-statutory list called the Victorian Threatened Species Advisory Lists (DEPI 2014). These two lists have recently been consolidated into one comprehensive list under the FFG Act referable to as the FFG Threatened List (DELWP 2022c) and the Advisory list has now been revoked.

2.5 Nomenclature and taxonomy

All scientific names, common names and systematic orders of flora and fauna species follow the Victorian Biodiversity Atlas (DELWP 2022b), with common names referring to fauna within the text of the report.

Where an asterisk (*) precedes a plant name it is used to signify non-indigenous taxa, those species which have been introduced to Victoria or Australia. A hash (#) is used to denote Victorian plant species that are not indigenous to the region or local area.

3 Results

Vegetation and frog monitoring were undertaken at the same sites (with two additional sites for frogs). Findings for each site are presented below followed by site summaries in Section 3.2.4.

The aquatic ecology monitoring was carried out at sites in different locations to the terrestrial monitoring sites and as such the site summaries are presented separately in Sections 4.3.

3.1 Vegetation

Site summaries displaying the results of vegetation monitoring are provided in Figure 9, Figure 10, Figure 11, Figure 12, Figure 13, Figure 14, Figure 17, Figure 18, Figure 19 and Figure 20.

3.1.1 Floristic composition

A total of 29 vascular indigenous plant species were recorded across all sites in the Anglesea Swamp, while no exotic species were recorded (Appendix 1). In the Anglesea Estuary, 17 plant species were indigenous (62.9%), eight plant species were exotic (29.6%) and two plant species were native Victorian species not indigenous to the study area (7.4%) (Appendix 2). Species richness in the Anglesea Swamp increased from 26 to 29 species between 2020 and 2021, while in the Anglesea Estuary sites, total species richness decreased by one species from 27 to 26 and native species richness decreased from 17 to 16 between 2020 and 2021.

Changes in species richness were variable across sites. At 3 of the 6 Anglesea Swamp sites, species richness increased, while one site remained stable, and two sites decreased in the total number of species recorded compared to the 2020 monitoring season (Figure 2). Across the Anglesea Estuary, species richness remained stable at two sites and decreased at two sites compared to the 2020 monitoring period (Figure 2). Furthermore, native species richness varies across sites, ranging from 6–16 in the swamp and 6–12 in the estuary (Table 3).

Table 3 Number of native plant species and associated functional groups recorded across Anglesea Borefield ecological Monitoring and Assessment Program sites

Transect/Site	Total number of native plant species	Number of plant species in a dry FG	Number of Amphibious FG plants	Number of plant species in an Aquatic FG
Anglesea Swamp				
AS2	16	9	3	4
AS3	10	2	7	1
AS4	14	3	8	3
ASP7_2014	15	2	10	3
AS1_2014	12	3	6	3
AGP2_2014	6	1	3	2
Anglesea Estuary				
LAR1	9	3	4	2
LAR2	12	6	4	2
LAR3	12	6	4	2
LAR4	6	1	3	2

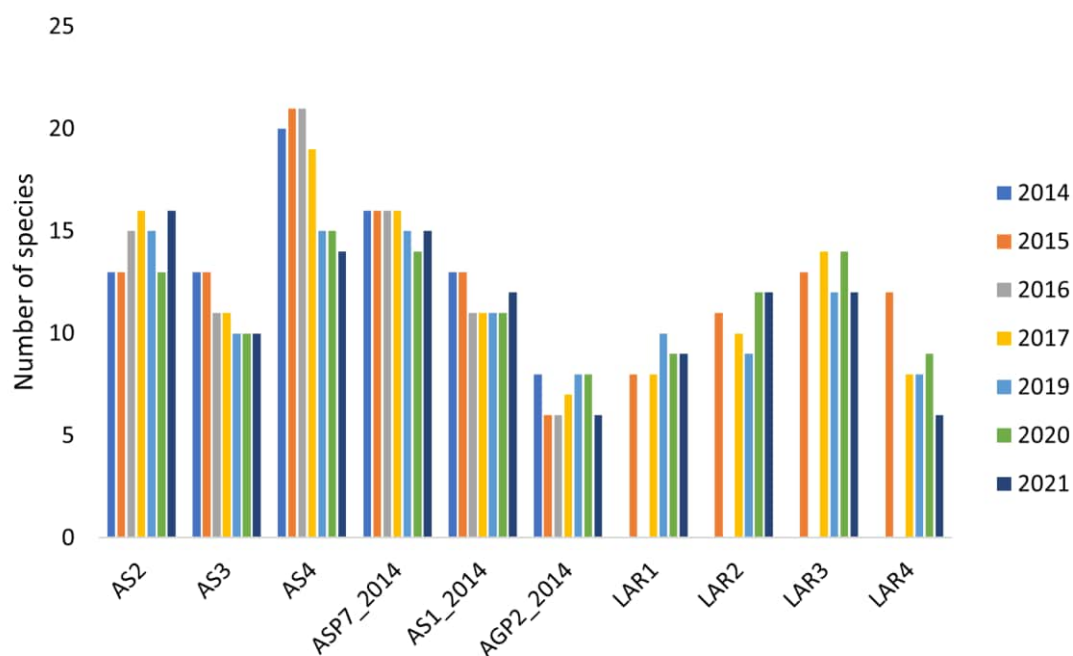


Figure 2 Native species richness at each survey site in the Anglesea Swamp (AS2, AS3, AS4, ASP7_2014, AS1_2014 and AGP2_2014) and the Anglesea Estuary (LAR1, LAR2, LAR3 and LAR4) for each season which required monitoring.

3.1.2 Species composition across years

The Anglesea Swamp NMDS ordination showed a large and distinct difference in species community composition between the 2019, 2020, and 2021 surveys and the 2014, 2015, 2016 and 2017 surveys (Figure 3). In addition, community composition in 2015 differed from 2014, 2016 and 2017. The difference between these groups of years was greatly driven by the reduction in frequency of common water-ribbons *Cyanogeton procerum* sp. aff. from near 80% in 2016 and 2017 to approximately 65% in 2019-2021. The other species driving differentiation between years were primarily dry land species associated with the Heathy Woodland EVC. This EVC fringes the wetland ecosystems and makes up a very small proportion of the monitored quadrats. Changes within dryland species composition such as this are not indicative of meaningful changes in the swamp vegetation between years.

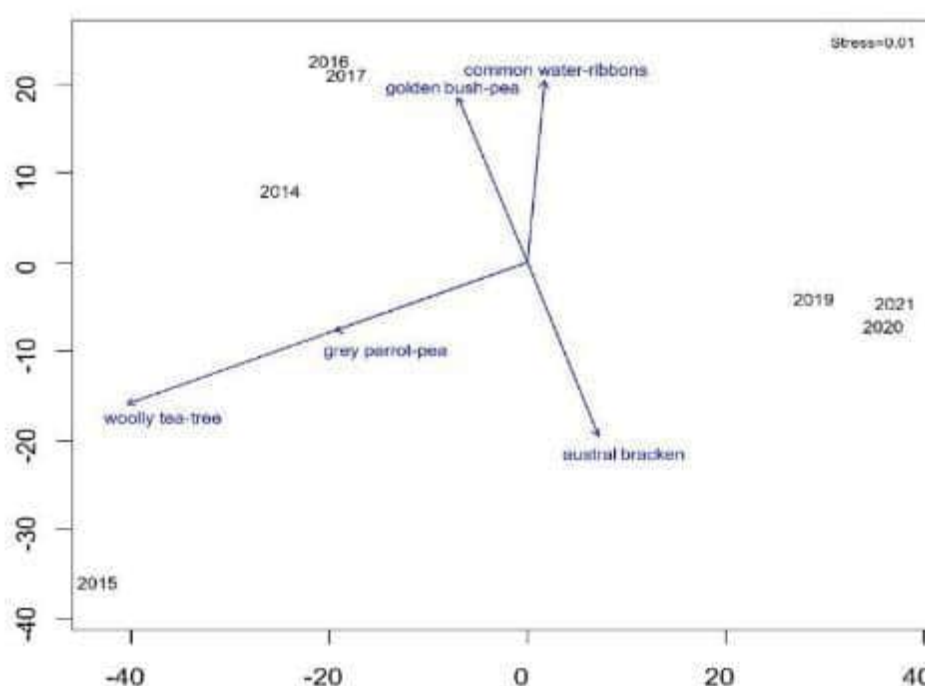


Figure 3 NMDS ordination of among-year variation in plant species composition across all Anglesea Swamp sites for all monitoring years. Lines show statistically significant ($p = 0.01$) vectors indicating strength of each species' association with each year.

The Anglesea Estuary NMDS ordination showed that weak similarity in species composition between all years. This result could not be easily explained and there appears to be large variability between species, sites and years (Figure 4).

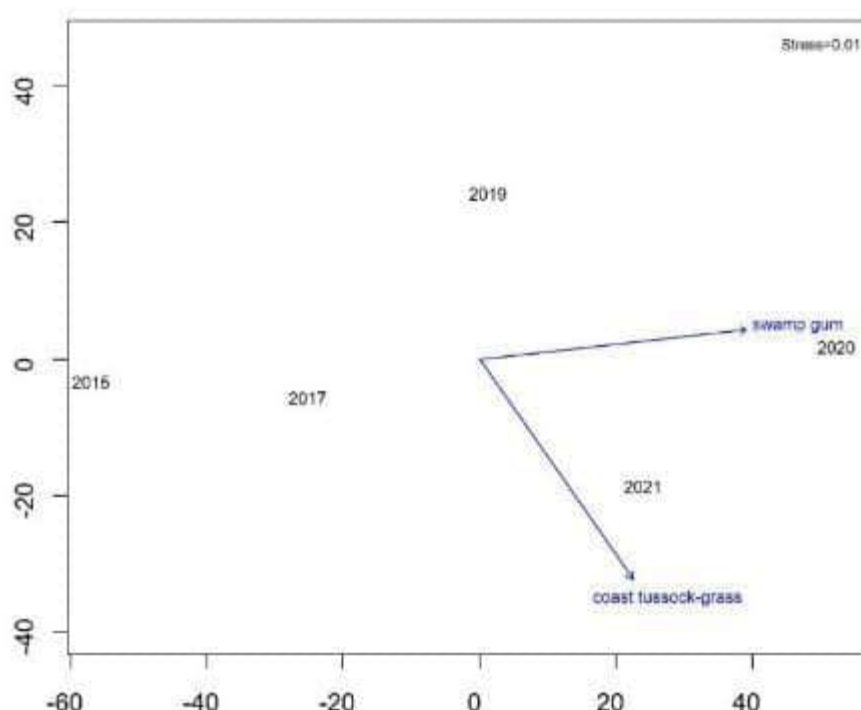


Figure 4 NMDS ordination of species composition across all Anglesea Estuary sites for all monitoring seasons. Lines show statistically significant ($p = 0.05$) vectors indicating strength association with each year.

3.1.3 Plant functional groups

Anglesea Swamp

In the Anglesea Swamp, six FGs were represented (T, Tdr, Se, Atw, Atl and Ate), while no species from Arp functional group were recorded (Table 3). The manuka *Leptospermum scorparium* (Tda) was recorded in previous years however, this species was not recorded present in the 2021 monitoring period. This is not due to a local extinction of the species but due to taxonomic difficulty. The prickly tea-tree *Leptospermum continentale* (Tdr) and the manuka (Tda) have proven to be difficult to distinguish between in the field. Therefore, for this year's analysis, all records of prickly tea-tree and manuka were grouped together as tea-tree *Leptospermum spp.* and assigned the summary functional group of T (Terrestrial).

The average frequency of Aquatic FGs (Se) across all Anglesea Swamp sites showed a slight increase from 67% in 2019 to 72% in 2021, however the average frequency still remained lower than the first four monitoring years (Figure 5). Overall, average frequency of Dry FGs (T, Tda, Tdr) continued to decrease slightly each monitoring season from 29% in 2014 to 24% in 2021. The average frequency of Amphibious FG's (Atw, Ate, Atl, Arp) has remained relatively consistent ranging from 83 – 86 %, apart from 2019 which showed an increase to 90% average frequency across all sites (Figure 5). The 2021

rainfall data from Aireys Inlet shows an average annual rainfall of 631 mm from 1994 to 2021 (BOM 2022) and the 2021 rainfall was above average 726 mm.

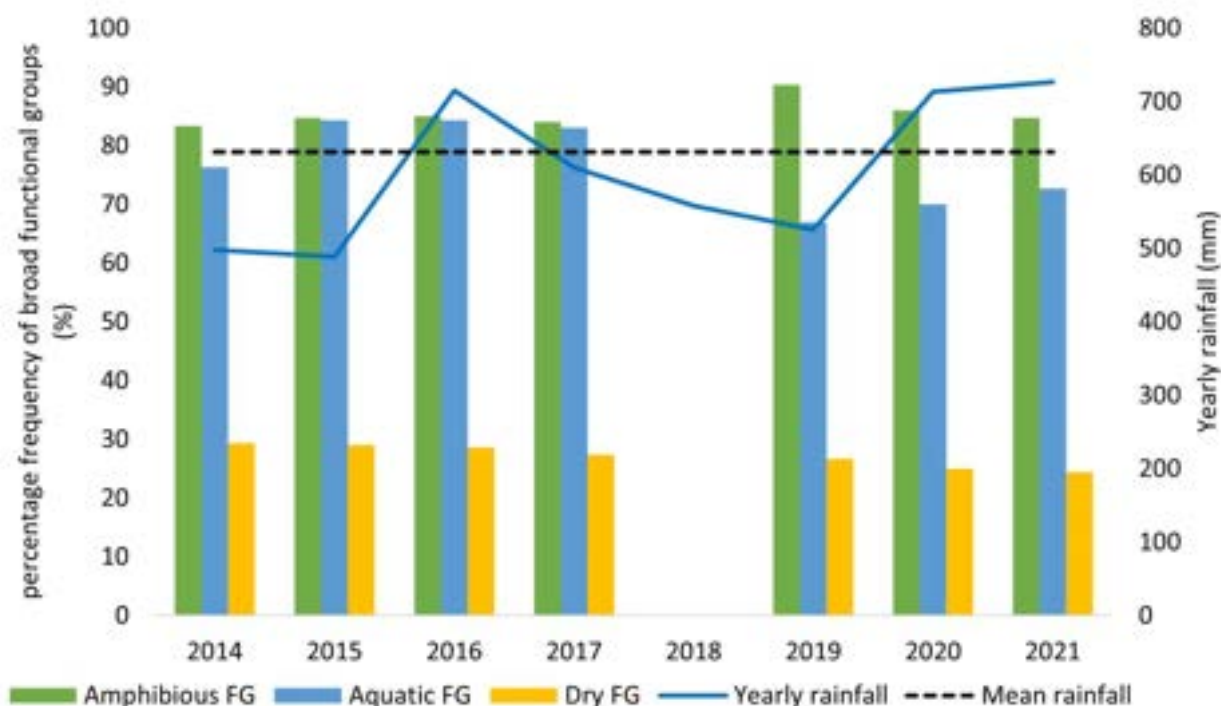


Figure 5 Average percentage frequency of broad functional groups (Amphibious FG, Aquatic FG and Dry FG) (left y-axis) and yearly and mean annual rainfall (right y-axis) across all sites in the Anglesea Swamp for each monitoring period. Swamp sites were not monitored in 2018 due to no water extraction to triggering monitoring.

Anglesea Estuary

Plants from seven FG's were recorded in the Anglesea Estuary (T, Tda, Tdr, Se, Ate, Atl, Arp), while no species from the Atw FGs were recorded (Table 3). Prickly tea-tree and manuka were treated the same as in the swamp and combined with tea-tree *Leptospermum spp.*(T).

The average frequency of Aquatic FGs (Se) across all Anglesea Estuary sites exhibited a slight increase from 51% in 2020 to 59 % in 2021, however, this remains lower than all other monitoring years which ranged from 84 – 86 % (Figure 6). The average frequency of Amphibious FGs in 2021 was 89.5% which remained relatively consistent with 2015 – 2019 results despite the decrease in 2020 to 72%. The average frequency of Dry FGs has fluctuated, however 2021 represented an increase from 53% in 2019 to 71% in 2021 (Figure 6).



Figure 6 Average percentage frequency of broad functional groups (Amphibious FG, Aquatic FG and Dry FG) (left y-axis) across all sites in the Anglesea Estuary for each monitoring period and yearly and mean annual rainfall (right y-axis). Estuary sites were not monitored in 2016 and 2018 due to no water extraction triggering monitoring.

Algal mats

Algal mats remained absent from sites AS2 and AS3 and have not been recorded in ASP7_2014 since 2019. Algal mats continue to be present in AS1_2014, AG2_2014 and AS4 with a large increase in the percentage of quadrats containing algae at AS4 from zero in 2020 to 58% of quadrats in 2021 (Figure 7). Algal mats were not recorded in any of the Anglesea Estuary sites in 2021 (Figure 7).

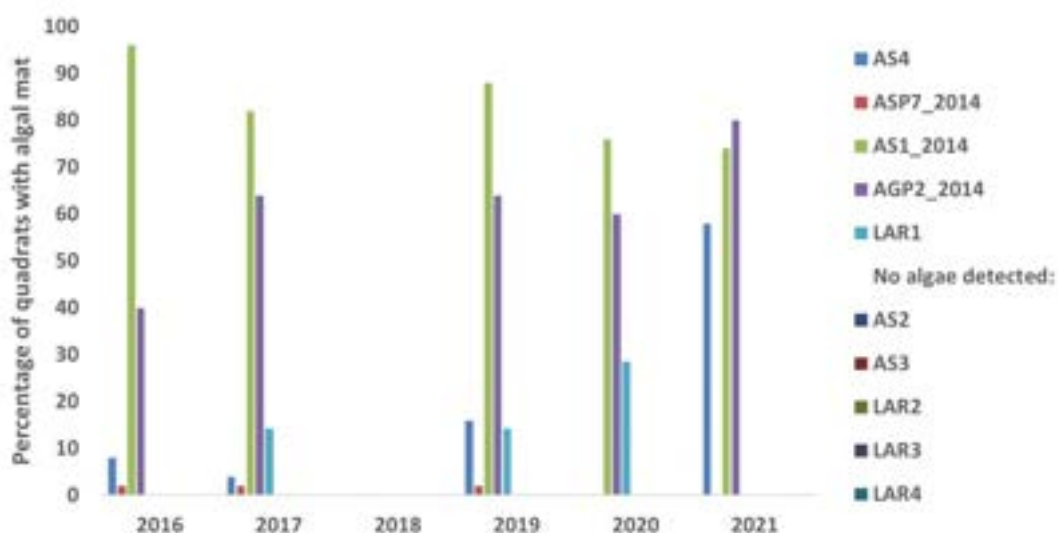


Figure 7 Algae mat records at all sites in the Anglesea Swamp and Anglesea Estuary from first detection in 2016. No monitoring was undertaken in the Anglesea Swamp 2018 or in the Anglesea Estuary in 2016 or 2018 due to no water extraction triggering monitoring.

3.2 Frogs

3.2.1 Survey conditions

The 8 sites at Anglesea Swamp all held water during the first survey period, with an average water depth at the site approximately 31 cm. Water depth at the study sites decreased by the second survey period to an average depth of approximately 8 cm. One site (AS5) had dried completely. At the estuary sites, the water depth remained relatively constant.

Weather conditions recorded during the two survey periods are summarised in Table 4.

Table 4 Weather conditions during frog surveys, 2021

Variable	Survey 1	Survey 2
Temperature (°C)	16.5	16.3
Humidity (%)		73
Cloud cover (0–8)	4	0
Moon light (0–4)	3	4
Wind speed (0–3)	0	0
Rainfall during survey (0–3)	0	0
Rain in past 24 hours (None–heavy)	Moderate	None

3.2.2 Frog species richness and abundance

The number of frogs estimated to be calling within 100 m of the study sites is provided in Figure 8. Since 2014 the number of frogs has varied every year, peaking in 2016 for the swamp sites and in 2020 for the estuary sites. The common froglet was the most abundant frog species at the swamp sites in 2021 and had the highest number of individuals detected since 2014. The number of southern bullfrogs also increased this year, with all other species at the other sites decreasing in abundance from last year.

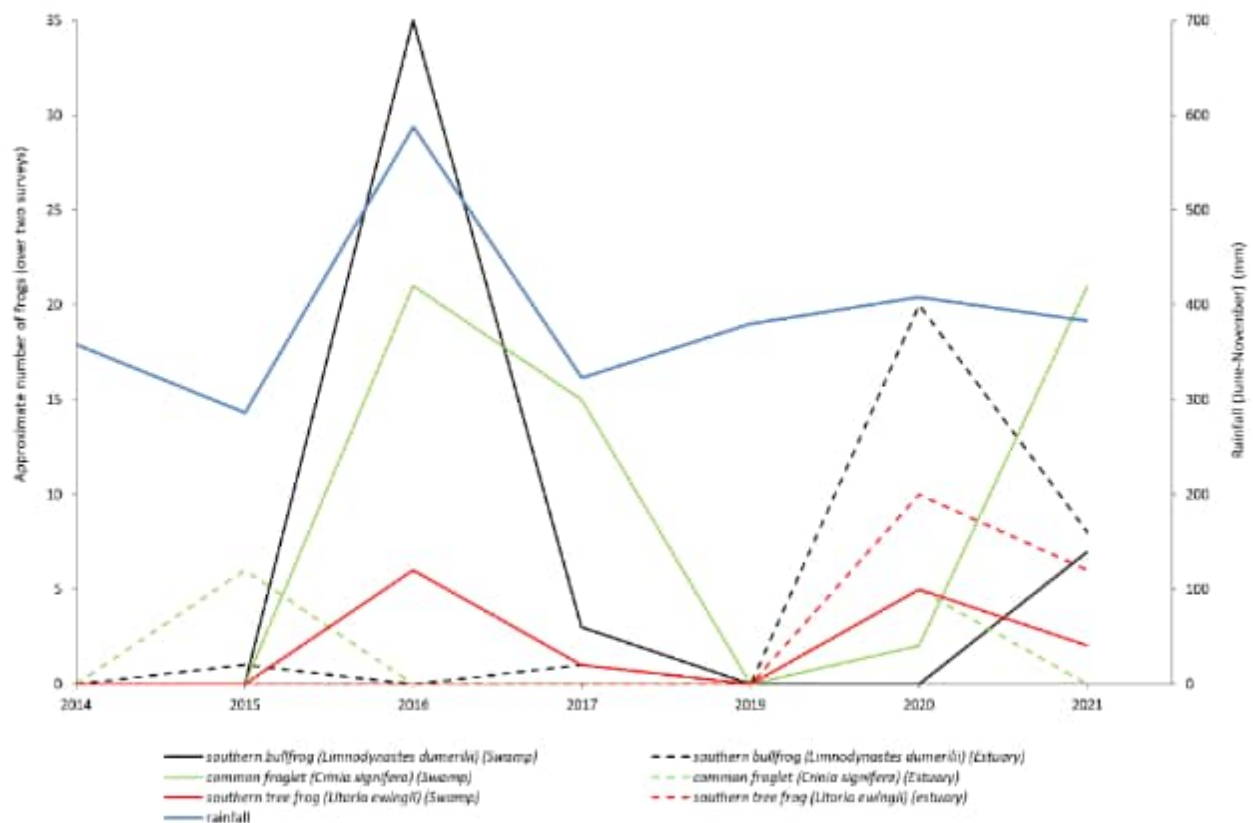


Figure 8 The number of frogs heard calling within 100 m of the survey sites at Anglesea Swamp and Anglesea Estuary from 2014 to 2021. Included in the mean winter to spring rainfall at Aireys Inlet (blue line).

Anglesea Swamp

Frogs were recorded from 3 of the 8 sites at Anglesea Swamp within 100m of the site (Table 5). Frogs were heard calling from more than 100m away at 6 of the 8 sites. All the records were from calling male frogs, and none were visually sighted. Only 3 species were recorded at the site: southern brown tree frog *Litoria ewingii*, common froglet *Crinia signifera* and southern bullfrog (pobblebonk) *Limnodynastes dumerilii*.

Site AS2 showed the highest species richness with all three species recorded from that site during the first survey. If frogs calling from more than 100 m were taken into account, then AS4 and AS3 also had all 3 species present.

Table 5 Frog species detected during nocturnal surveys and estimated abundances at the Anglesea Swamp sites. The number of frogs heard calling more than 100 m from the survey sites are listed in parentheses.

Site	Southern Brown Tree Frog		Common Froglet		Southern Bullfrog (Pobblebonk)		Species richness
	1	2	1	2	1	2	
AS1_2014	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0
AS2	2 (0)	0 (0)	11-20 (0)	0 (0)	6-10 (0)	1 (0)	3
AS3	0 (1-5)	0 (0)	1-5 (0)	0 (0)	0 (6-10)	0 (0)	1
AS4	0 (1-5)	0 (0)	0 (1-5)	0 (0)	0 (3)	0 (0)	0
AS5	0 (1-5)	0 (0)	0 (0)	0 (0)	0 (1)	0 (0)	0
AS6	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0
ASP7_2014	0 (2)	0 (0)	1-5 (0)	0 (0)	0 (0)	0 (0)	1
AGP2_2014	0 (1)	0 (0)	0 (0)	0 (0)	0 (1)	0 (0)	0

Anglesea Estuary

Frogs were recorded at all 4 of the Anglesea Estuary sites (Table 6). In contrast to the Anglesea Swamp sites, the common froglet was not detected from any of the estuary sites. Site LAR1 was the only site where both the southern brown tree frog and southern bullfrog (pobblebonk) were heard. The southern brown tree frog was the most often heard frog during the second survey, with only 1 site (LAR2) recording any frogs within 100 m of the site.

Table 6 Frog species detected during nocturnal surveys and estimated abundances at the Anglesea Estuary sites, 2021. The number of frogs heard calling more than 100 m from the survey sites are listed in parentheses.

Site	Southern Brown Tree Frog		Common Froglet		Southern Bullfrog (Pobblebonk)		Species Richness
	1	2	1	2	1	2	
LAR1	0 (0)	2 (0)	0 (0)	0 (0)	0 (0)	5-10 (0)	2
LAR2	0 (2)	1-5 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1
LAR3	0 (1)	0 (0)	0 (0)	0 (0)	5-10 (0)	0 (0)	1
LAR4	0 (1)	1 (0)	0 (0)	0 (0)	0 (0)	0 (0)	1

3.2.3 Habitat assessment and water quality

Anglesea Swamp

The Anglesea Swamp monitoring sites mostly support dense shrub cover of scented paperbark *Melaleuca squarrosa* and prickly teatree *Leptospermum continentale*, which open up into clearings of emergent aquatic vegetation, largely sedges such as zig-zag bog-sedge *Schoenus brevifolius*, square twig-sedge *Machaerina tetragona* and fine twig-sedge *M. arthrophylla*. Swards of dead and live sedges occasionally form thick mats across the site. Fringing vegetation sometimes includes shorter pink swamp-heath *Sprengelia incarnata* or pouched coral-fern *Gleichenia dicarpa*. Where monitoring sites support standing water, common water-ribbons *Cycnogeton procerum* sp. aff. and filamentous algae may be present as submergent and floating vegetation. Some sites also include small patches of bare ground and low cover of woody debris, especially at the interface between emergent and fringing vegetation.

All monitoring sites are considered intermittent except for AS3 (semi-permanent) and AS4 (semi-permanent to permanent). During the 2021 surveys, all sites had sufficient standing water to allow for all water quality parameters to be measured during the first survey. This had declined by the second survey such that three sites (AS2, AS3, AS6 and ASP7) had insufficient standing water for reliable water quality measurement. Sites were acidic (pH of 2.65–3.97) and electric conductivity was low to moderate, ranging from 0.67 to 1.86 ms/cm. Water temperatures were relatively high, with all but three measurements above 15 °C (range: 16.5–19.7 °C). Turbidity was more variable across sites, being generally low (range: 0–52 NTU) with most values being under 15 NTU. Similarly, dissolved oxygen levels were variable (range: 7.9–18.8 mg/L), with only 3 sites able to be measured during the second survey.

Anglesea Estuary

The Anglesea Estuary is relatively deep, with slow-moving water. Apart from filamentous algae, the cover of aquatic vegetation was generally low, particularly the cover of floating and submergent vegetation. Common reed *Phragmites australis* is an emergent species that provides sparse emergent vegetation at most sites. Fringing vegetation occurs at higher levels of cover, dominated by grasses, sedges, rushes and herbs including cast tussock-grass, *Poa poiformis* var. *poiformis*, common blown-grass *Lachnagrostis filiformis*, sea rush *Juncus kraussii* ssp. *australiensis* and shiny swamp-mat *Goodenia radicans*. LAR1 also supports narrow-leaf cumbungi *Typha domingensis* and southern water-ribbons. Scattered shrubs of hop goodenia *Goodenia ovata*, manuka *Leptospermum scoparium* and stands of swamp gum *Eucalyptus ovata* var. *ovata* were recorded near the water's edge.

All estuary monitoring sites are considered permanent, with stream widths ranging from 2–3 m to approximately 12 m wide, and up to 1–2 m deep. As such, water quality could be measured at all sites, and values were generally consistent between sites within surveys, compared to measurements taken in the Anglesea Swamp. All sites had very low pH (3.51–4.01), and water temperature below 10 °C during the first survey and 15–20 °C during the second survey. Electrical conductivity readings were relatively low during the first survey (3.5–4.0 ms/cm), with significantly higher EC (12.5–14 ms/cm) during the second survey. Conductivity remained relatively constant, with a mean of 7.82 ms/cm in the first survey, to 7.85 ms/cm in the second survey, a change in mean from 1.67 ms/cm to 12.93 ms/cm. Turbidity was low (0–2 NTU) and dissolved oxygen concentrations varied from 8.3 to 15.5 mg/L.

3.2.4 Vegetation and frog site summaries

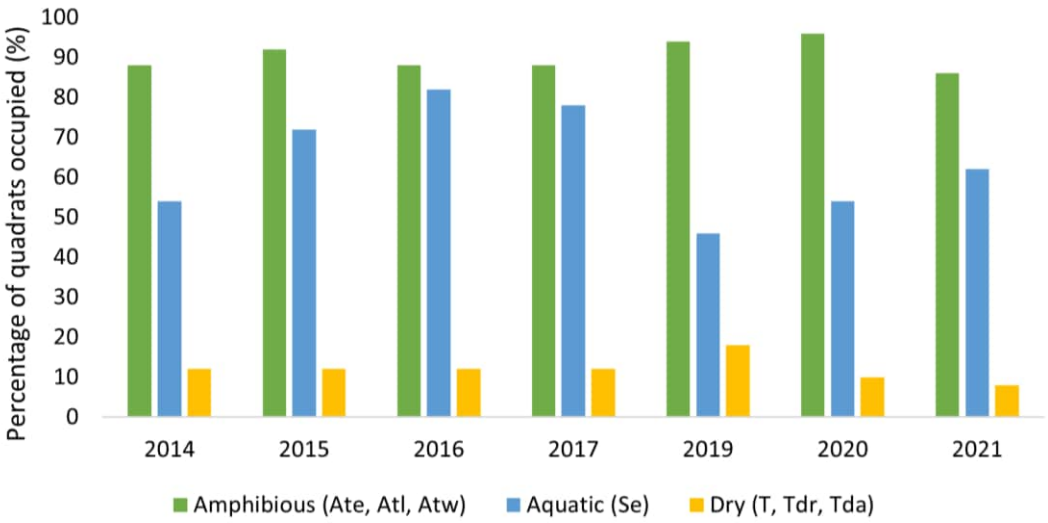
The following site summaries include:

- transect photos at 25 m intervals
- the proportion of each FG recorded at each site
- the top three dominant plant species and their FG
- other attributes including average water depth
- a habitat description
- frog species occurrence and abundance
- water quality data
- relevant comments.

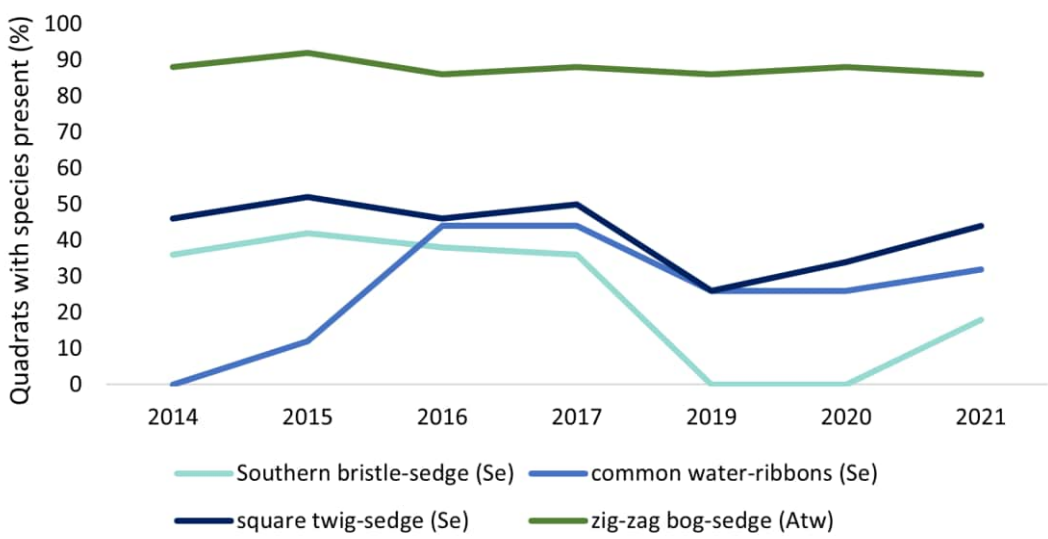
A



B



C



D

AS2 Great Blotch description					
Ecological Vegetation Class (EVC)			Aquatic Sedge and		
Waterbody name			Ephemeral		
Swampy brackish emergent dead and live sedges with patches of deeper open water at varying depths to 20 cm. Open water contains 5% floating 5% submerged vegetation and 0-10% emergent vegetation. The swamp is lined with 0-99% shrub and tree cover with 20-50% bare soil.					
AS2 Frog abundance and richness					
Southern Brown Tree Frog		Common Froglet		Southern Bell Frog	
2		11:20		6:10	
				3	
AS2 Water quality parameters					
Survey 1					
pH	397	Turbidity	30 NTU	Water temperature	12°C
EC	0.674 µs/cm	Salinity	0.02%	Dissolved Oxygen	9.88 mg/L
Survey 2					
pH	534	Turbidity	0.86 NTU	Water temperature	20°C
EC	19 µs/cm	Salinity	0.04%	Dissolved Oxygen	- mg/L
Comments					
Rods up to 50 cm depth were present during the first survey making conditions relatively good for frogs. All three species were heard during the first survey and responded to local playback. The common froglet was already calling prior to playback. As expected, no frogs were heard calling during the second survey or playback. By the second survey, water depth had increased less than 1 cm, providing very little good habitat for frogs.					

Figure 9 Agnes Reef Ecological Monitoring and Assessment Program Agnes Swamp Site AS2, 2021 including A) photographs, B) percentage of quadrats occupied by local Grassland monitoring years, C) percentage of top five dominant species across all monitoring years and D) frog survey data.

A



0-2m



2-5m

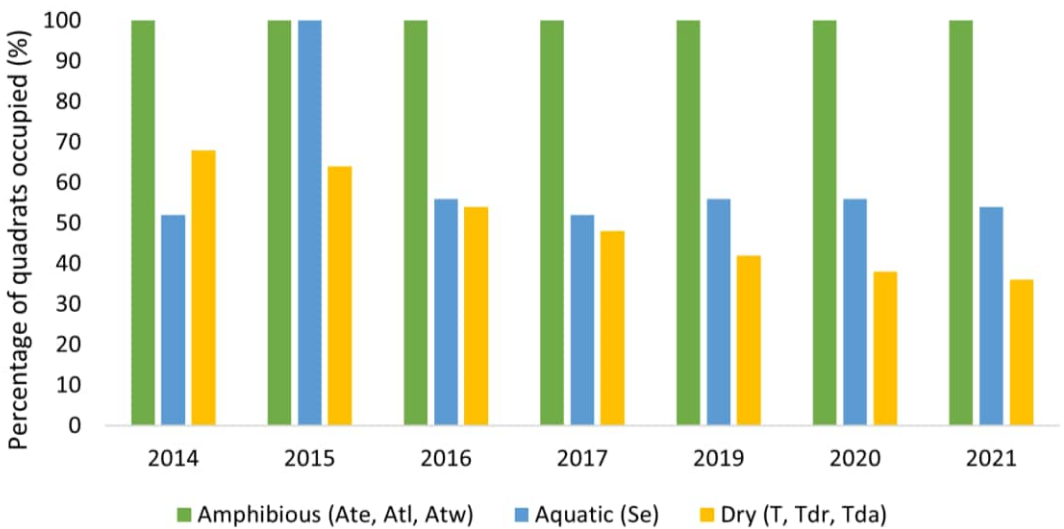


5-7m

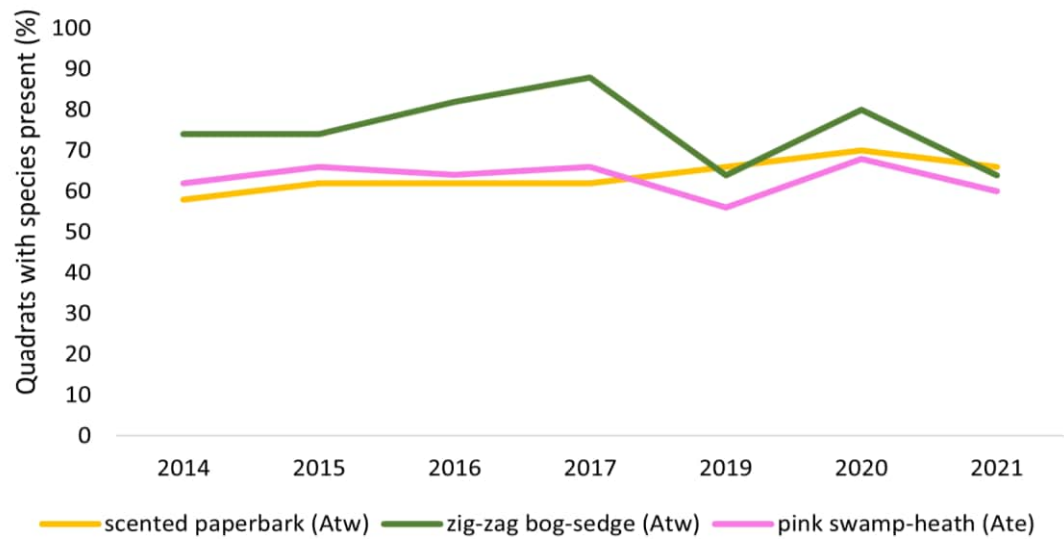


7-10m

B



C



D

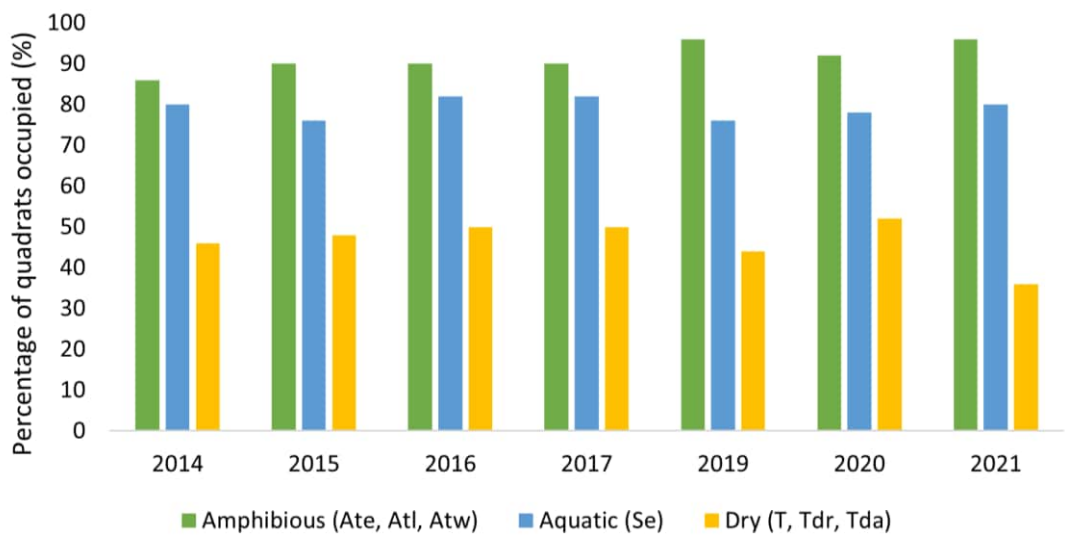
AS3 General site description					
Ecological Vegetation Class (EVC)			Swamp Scrub		
Water permanence			Semi permanent		
Site consists of small (<0.25 ha) clumps of shrub vegetation in wet vegetation mainly <i>Lymsp</i> , makes up 7-10% of the area proper. The site is mostly <i>Myrtus</i> species (7-10%) <i>Myrtus</i> species to depth 20 cm during the first survey and depth less than 10 cm by the second survey.					
AS3 Frog abundance and richness					
Southern Brown Tree Frog		Common Froglet		Southern Bell Frog	Species Richness
15		15		6:10	3
AS3 Water quality parameters					
Survey 1					
pH	3.67	Turbidity	13 NTU	Water temperature	11.9°C
EC	0.04 µs/cm	Salinity	0.04%	Dissolved Oxygen	156 mg/L
Survey 2					
pH	3.72	Turbidity	25 NTU	Water temperature	18.2°C
EC	1.9 µs/cm	Salinity	0.09%	Dissolved Oxygen	NA
Comments					
Water was adequate for measuring water quality during the first survey, but the level had dropped significantly by the second survey, making some parameters difficult to measure. Frogs were only heard during the first survey, with all species heard. Calling positions were estimated to be greater than 30 m away.					

Figure 10 Agnes Brief Ecological Monitoring and Assessment Program Agnes Swamp Site AS3, 2021 including A) photo points, B) percentage of quadrats occupied by local Grassland monitoring years, C) percentage of top three dominant species across all monitoring years and D) frog summary data.

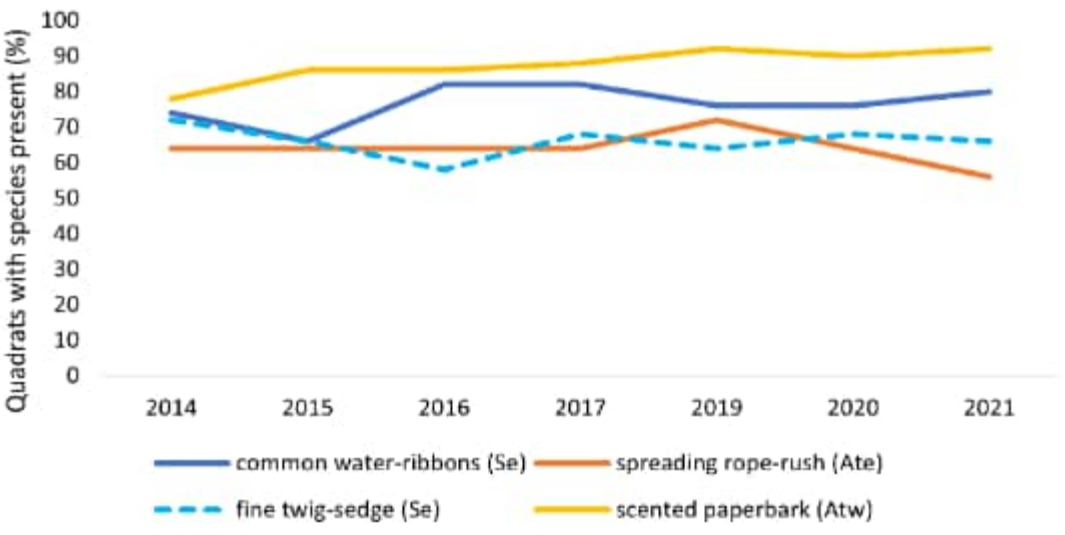
A



B



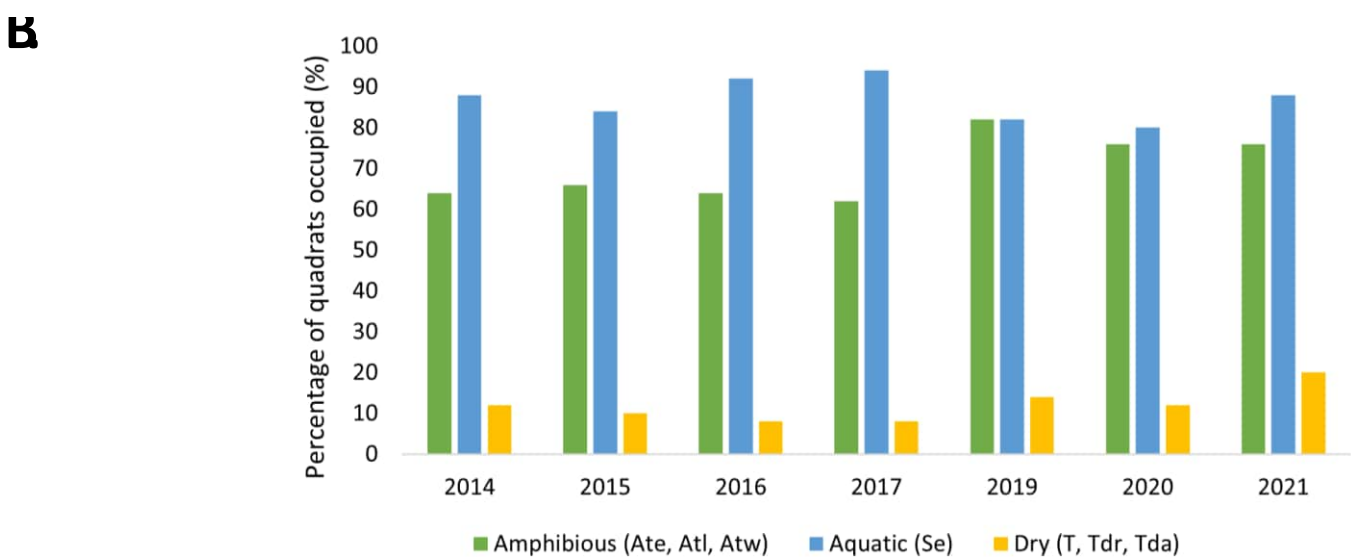
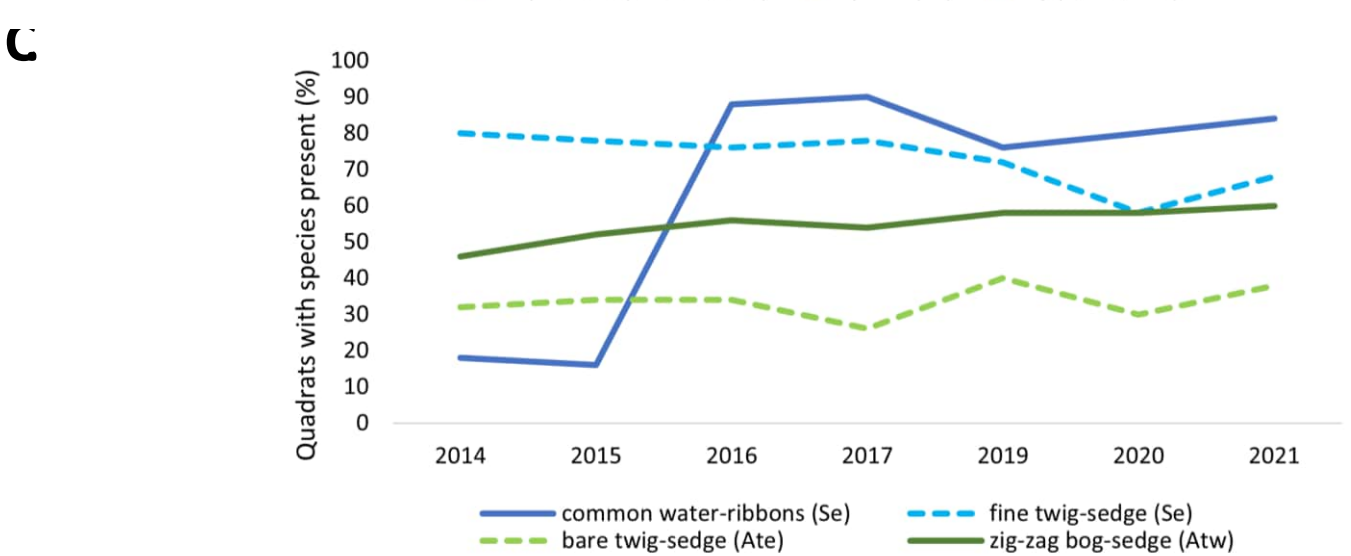
C



D

AS4 General site description					
Ecological Vegetation Class (EVC)			Aquatic Sedgebed		
Wetland type			Semi-permanent		
Survey site located on the perimeter of the swampy fringe vegetation. Fine twig sedge and scented paperbark (20-50%) submerged vegetation was absent with fringe vegetation consisting of scented paperbark. There was evidence of flooding in the area.					
AS4 Frog abundance and richness					
Southern Brown Tree Frog		Common Froglet		Southern Bell Frog	
15		15		3	
Species Richness		Species Richness		Species Richness	
3		3		3	
AS4 Water quality parameters					
Survey 1					
pH	3.76	Turbidity	0 NTU	Water temperature	11.8°C
EC	112 µs/cm	Salinity	0.04%	Dissolved Oxygen	7.49 mg/L
Survey 2					
pH	3.26	Turbidity	30 NTU	Water temperature	21.4°C
EC	153 µs/cm	Salinity	0.07%	Dissolved Oxygen	7.9 mg/L
Comments					
Frogs were only heard during the first survey. All three species were heard but calling was estimated to be more than 50m away.					

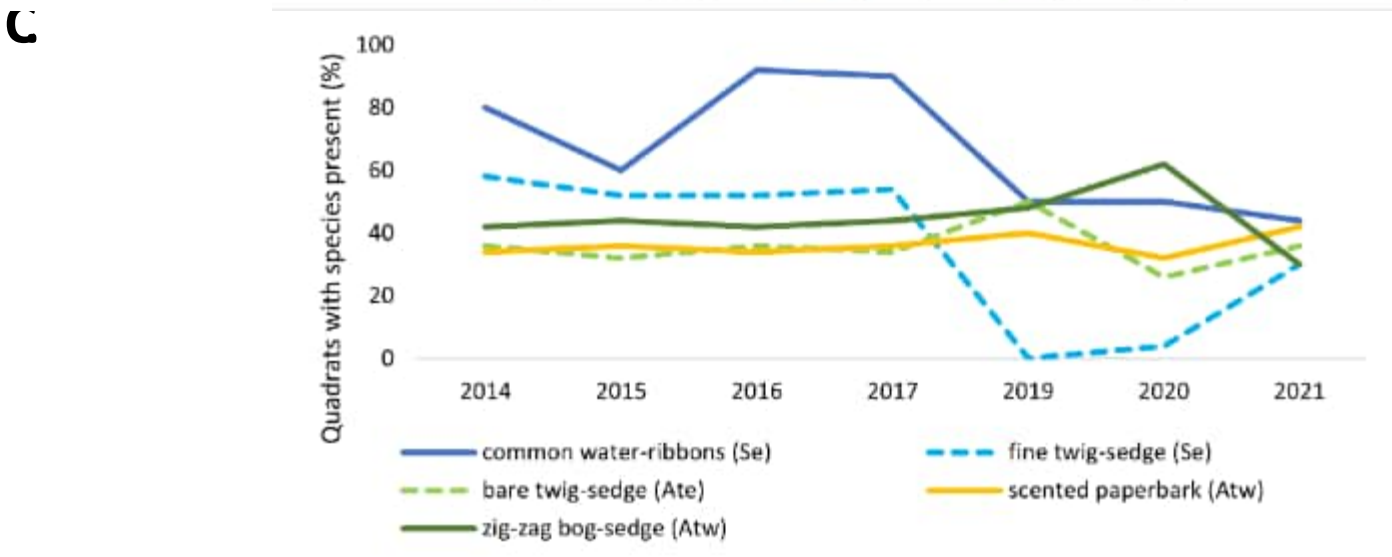
Figure 11 Agassal Brief Ecological Monitoring and Assessment Program Agassal Swamp Site AS4, 2021 including A) photographs, B) percentage of quadrats occupied by local Grassland monitoring years, C) percentage of top three dominant species across monitoring years and D) frog summary data.



D

ASP7_2014 Great hole description					
Ecological Vegetation Class (EVC)			Aquatic Sedge bed		
Water permanence			Ephemeral		
Site consists of a large (about 3 ha) clearing within the swamp, comprising 50-70% emergent sedges fringed with 20-100% cover of mostly sedge and paperbark. Some submerged (<5%) and floating plants (<5%) are present. During the first survey the swamp had an average depth of 0.2 m, the depth reduced during the second survey, revealing a substrate of sand and decomposing vegetation.					
ASP7_2014 Frog abundance and richness					
Southern Brown Tree Frog		Common Froglet		Southern Bullfrog	
2		15		0	
Species Richness		2			
ASP7_2014 Water quality parameters					
Survey 1					
pH	32	Turbidity	1 NIU	Water temperature	15.2°C
EC	123 µs/cm	Salinity	0.05%	Dissolved Oxygen	12.5 mg/L
Survey 2					
pH	32.2	Turbidity	52 NIU	Water temperature	31.2°C
EC	174 µs/cm	Salinity	0.08%	Dissolved Oxygen	NA
Comments					
By the second survey, the water level was very shallow, too shallow to measure dissolved oxygen. The low water level is likely responsible for the high turbidity and high water temperature. Frogs were recorded during the first survey only, with 2 southern brown tree frogs heard during the first survey and 15 heard during the second survey.					

Figure 12 Agnes Reef Ecological Monitoring and Assessment Program Agnes Swamp Site ASP7 2014, 2021 including A) photo points, B) percentage of quadrats occupied by local Gaoosall monitoring years, C) percentage of quadrats with species present Gaoosall monitoring years and D) frog summary data.



D

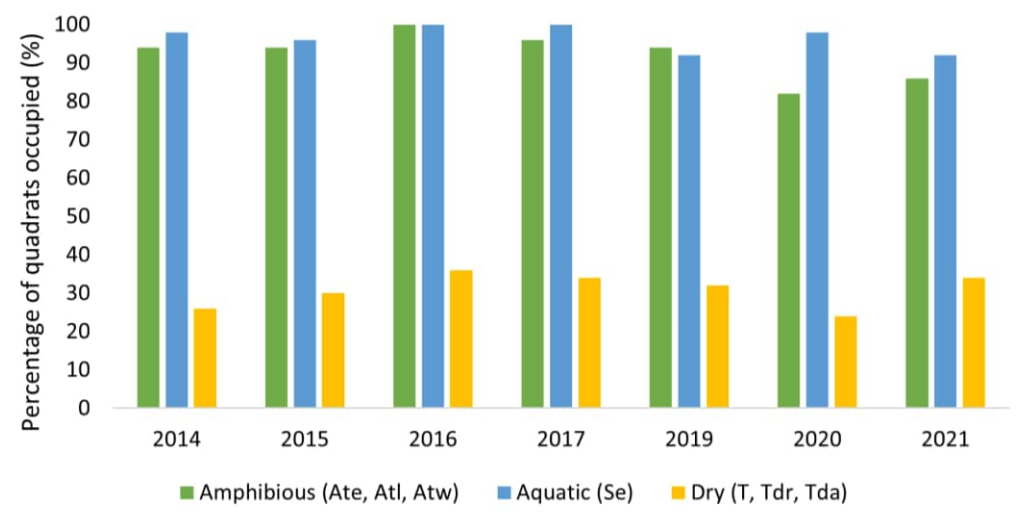
ASL_2014 Great hole description					
Ecological Vegetation Class (EVC)			Aquatic Sedge and		
Waterbody name			Ephemeral		
Mostly open swamp not completely lined with sedge paperbark and dry leaf litter consisting of 70-100% floating and submerged vegetation. In some areas (20-50%) sedge is present throughout the swamp. Some evidence of aquatic plants present.					
ASL_2014 Frog abundance and richness					
Southern Brown Tree Frog		Common Froglet		Southern Bell Frog	
Species Richness					
0		0		0	
ASL_2014 Water quality parameters					
Survey 1					
pH	2.76	Turbidity	0 NTU	Water temperature	20.9°C
EC	163 µs/cm	Salinity	60‰	Dissolved Oxygen	168 mg/L
Survey 2					
pH	2.82	Turbidity	6 NTU	Water temperature	31.1°C
EC	234 µs/cm	Salinity	0.11‰	Dissolved Oxygen	146 mg/L
Comments					
The depth of the swamp by the second frog survey was still suitable for water quality measurements. There were no frogs collected in either survey.					

Figure B Agnes Reef Ecological Monitoring and Assessment Program Agnes Swamp Site ASL 2014, 2021 including A: photographs, B: percentage of quadrats occupied by broad Gossam monitoring years, C: percentage of quadrats with species present, D: frog survey data.

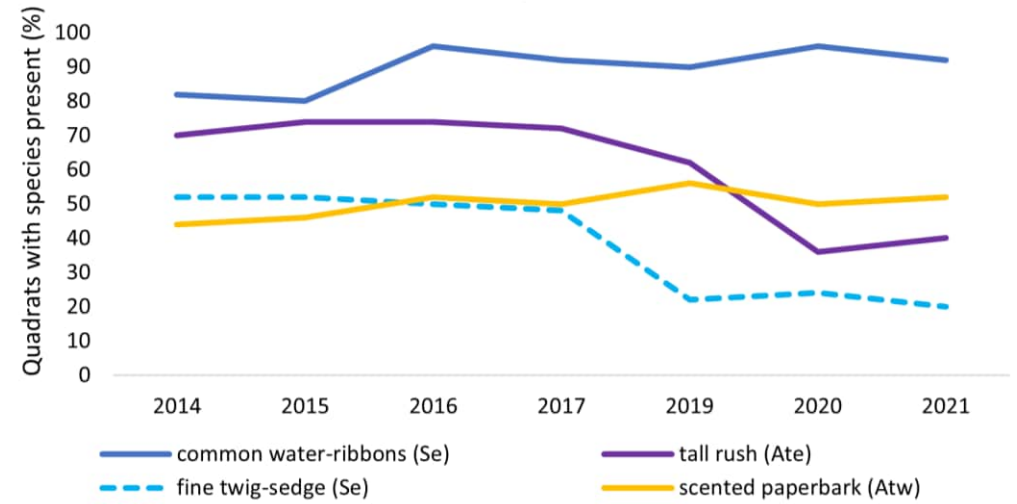
A



B



C



D

AGP2_2021 Great habitat description					
Ecological Vegetation Class (EVC)			Aquatic Sedgeland		
Vegetation Name			Epiphyt		
This is a small (0.25 ha) dead mangrove up to 4m tall, mostly dead paperbark and dry teatree (70-100%). Approximately 49% of area with 10.2% of area of living common water-ribbons, interspersed with reed rushes (10.5%) and dead scented paperbark. Living vegetation consisted of Gamba, common water-ribbon, and rushes (50.7%), with submerged common water-ribbon (5.1%).					
AGP2_2021 Frog abundance and richness					
Southern Brown Tree Frog		Common Froglet		Southern Bell Frog	Species Richness
1		0		1	2
AGP2_2021 Water quality parameters					
Survey 1					
pH	26	Turbidity	UNU	Water temperature	16°C
EC	180 µS/cm	Salinity	0.08%	Dissolved Oxygen	188 mg/L
Survey 2					
pH	294	Turbidity	26 NU	Water temperature	25°C
EC	182 µS/cm	Salinity	0.09%	Dissolved Oxygen	158 mg/L
Comments					
The only frog collected was a small toad toad from the 30m away from the site.					

Figure 14 Agnes Reef Ecological Monitoring and Assessment Program Agnes Swamp Site AGP2 2014-2021 including A) photo points, B) percentage of quadrats occupied by local Gaoosall monitoring years, C) percentage of quadrats with species present monitoring years and D) frog survey data

AS5: General habitat description					
Ecological Vegetation Class (EVC)			Aquatic Sedgeland		
Wetland permanence			Ephemeral		
The small (0.25 ha) section of swamp was generally moist with occasional deeper depressions. The vegetation, consists of sedges surrounded by 70-100% cover of fringing prickly tea-tree and scented paperbark.					
AS5: Frog abundance and richness					
Southern Brown Tree Frog		Common Froglet		Southern Bullfrog	Species Richness
1-5		0		1	2
AS5: Water quality parameters					
Survey 1					
pH	3.44	Turbidity	1 NTU	Water temperature	12.3 °C
EC	1.14 µs/cm	Salinity	0.07 %	Dissolved Oxygen	8.5 mg/L
Survey 2					
pH	Dry	Turbidity	Dry	Water temperature	Dry
EC	Dry	Salinity	Dry	Dissolved Oxygen	Dry
Comments					
Water levels were adequate for measuring water quality parameters during the first survey. By the second survey the site was dry. Frogs were only heard calling during the first survey, both species estimated to be more than 300m away from the site.					

Figure 15 Anglesea Borefield terrestrial revised ecological Monitoring and Assessment Program, Anglesea Swamp site AS5, 2021 frog summary data.

AS6: General habitat description					
Ecological Vegetation Class (EVC)			Aquatic Sedgeland		
Wetland permanence			Ephemeral		
Swamp relatively shallow (to 0.15 m) consisting of emergent (10-20%) vegetation consisting of decomposing sedges, small clumps of live sedges and scented paperbark. Submergent and floating vegetation was absent with the swamp fringed by 70-100% of scented paperbark.					
AS6: Frog abundance and richness					
Southern Brown Tree Frog		Common Froglet		Southern Bullfrog	Species Richness
0		0		0	0
AS6: Water quality parameters					
Survey 1					
pH	5.4	Turbidity	2 NTU	Water temperature	20.8 °C
EC	1.79 µs/cm	Salinity	0.08 %	Dissolved Oxygen	16.08 mg/L
Survey 2					
pH	2.81	Turbidity	32 NTU	Water temperature	25.3 °C
EC	2.04 µs/cm	Salinity	0.09 %	Dissolved Oxygen	NA
Comments					
Water levels were too low to measure dissolved oxygen during the second survey. The low water level is reflected by the water parameters. No frogs were heard calling during either survey.					

Figure 16 Anglesea Borefield terrestrial revised ecological Monitoring and Assessment Program, Anglesea Swamp site AS6, 2021 frog summary data.

LAR1 vegetation and frog summary data

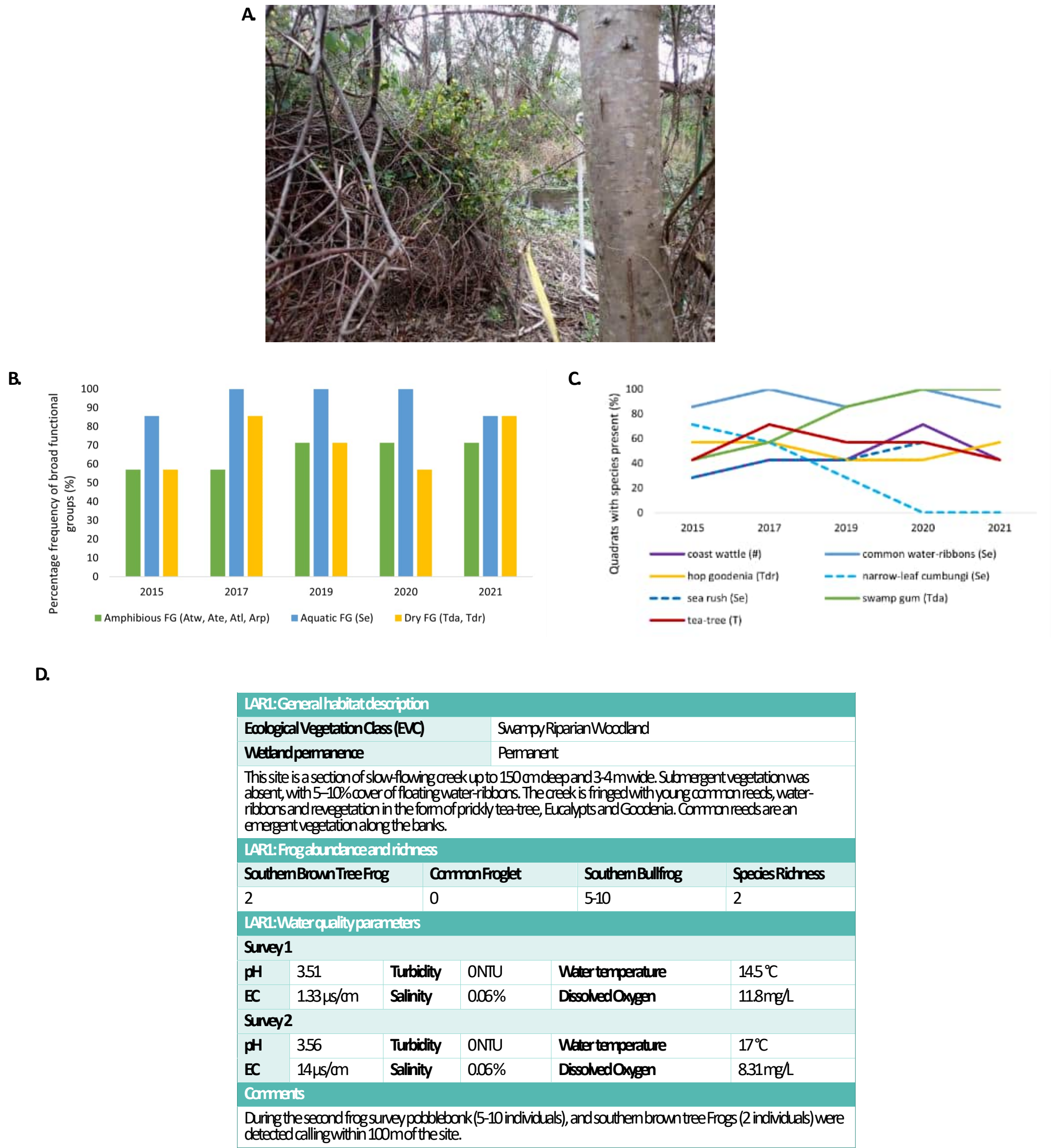


Figure 17 Anglesea Borefield Monitoring and Assessment Program, Anglesea Estuary, Site LAR1, 2021 including: A. photo points, B. percentage of quadrats occupied by broad FGs across all monitoring years, C. percentage of top three dominant species across all monitoring years and D. frog summary data

LAR2 vegetation and frog summary data

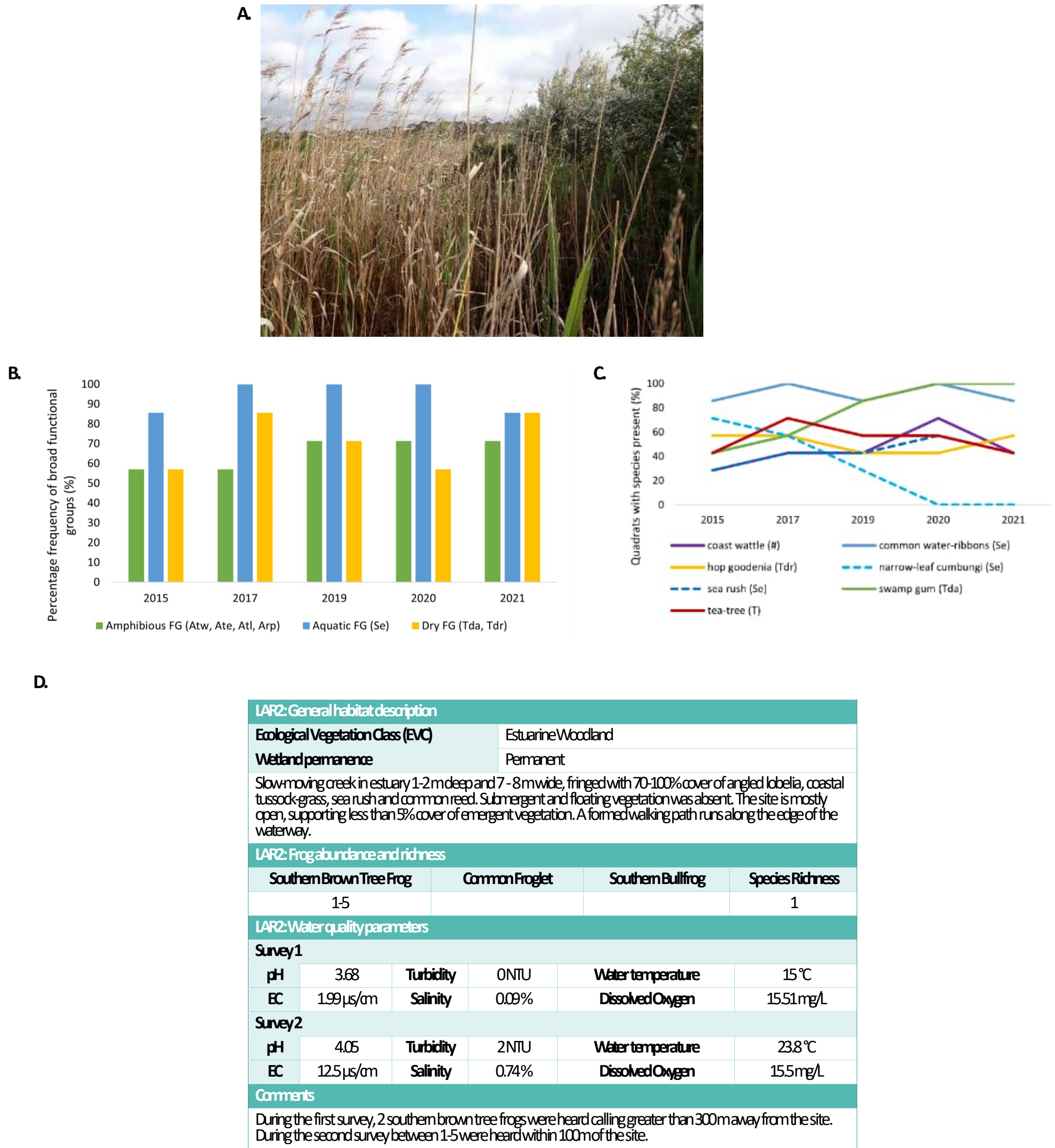


Figure 18 Anglesea Borefield Monitoring and Assessment Program, Anglesea Estuary, Site LAR2, 2021 including: A. photo points, B. percentage of quadrats occupied by broad FGs across all monitoring years, C. percentage of top three dominant species across all monitoring years and D. frog summary data

LAR3 vegetation and frog summary data

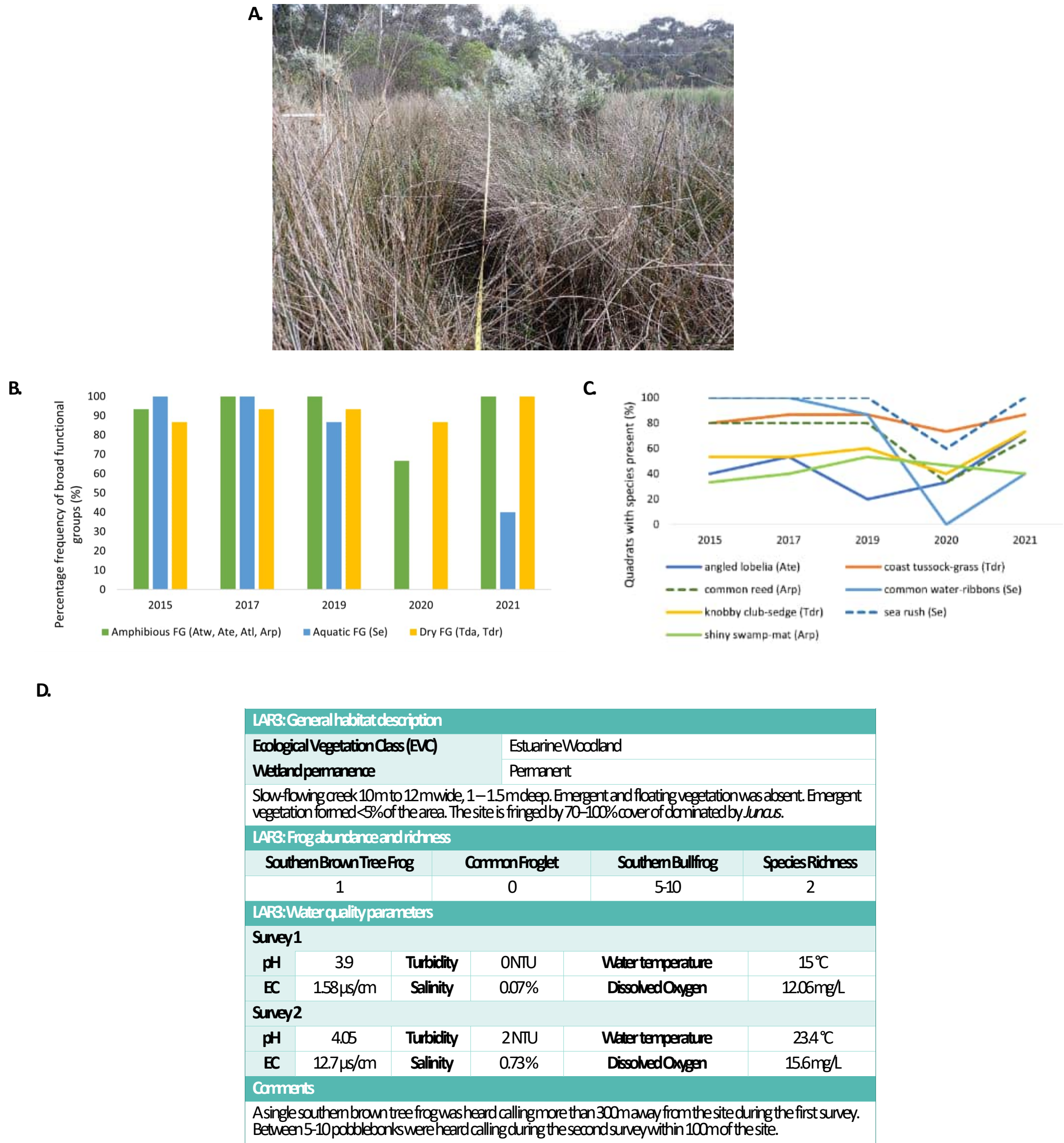


Figure 19 Anglesea Borefield Monitoring and Assessment Program, Anglesea Estuary, Site LAR3, 2021 including: A. photo points, B. percentage of quadrats occupied by broad FGs across all monitoring years, C. percentage of top three dominant species across all monitoring years and D. frog summary data

LAR4 vegetation and frog summary data

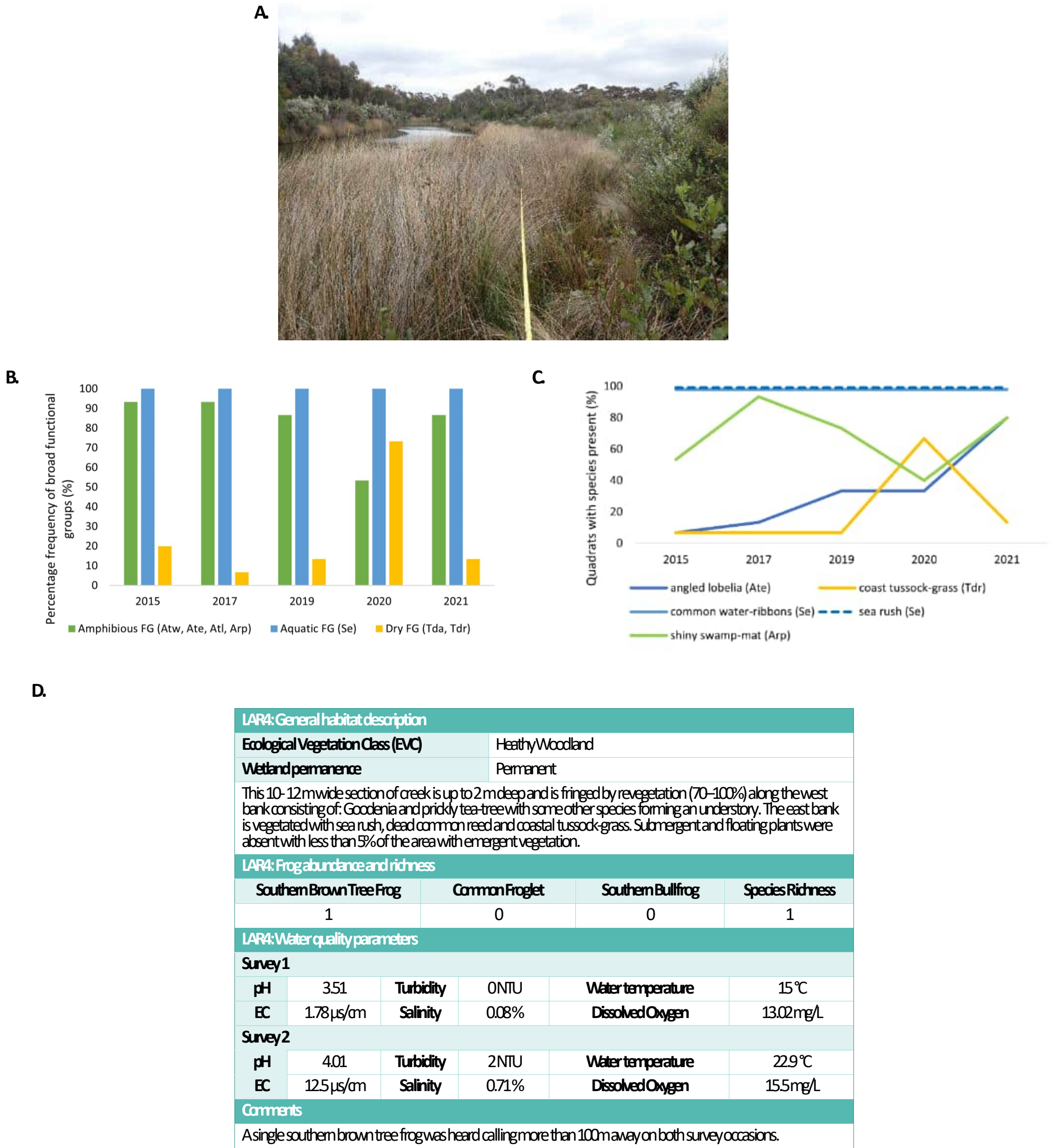


Figure 20 Anglesea Borefield Monitoring and Assessment Program, Anglesea Estuary, Site LAR4, 2021 including: A. photo points, B. percentage of quadrats occupied by broad FGs across all monitoring years, C. percentage of top three dominant species across all monitoring years and D. frog summary data

3.3 Macroinvertebrates

The macroinvertebrate results based on combined sample data from each site are provided in Table 7. Due to the very wet winter/spring in 2021 all sites had sufficient water to collect triplicate edge samples. No site met the objective for number of taxa listed in the State Environmental Protection Policy – Waters objective (SEPP (W); Vic. Gov. 2018; Table 7). The Breakfast Creek sites were the most diverse, followed by the upper Anglesea River sites and lower Anglesea River wetland 1. SIGNAL2 score objectives were met for all Breakfast Creek and tributary sites, Salt Creek and lower Anglesea River wetland 2 and 3. The number of Ephemeroptera, Plecoptera and Trichoptera (EPT) objective was met for one site, the most upstream Breakfast Creek site BC1. While not achieving the objective, all remaining Breakfast Creek and tributary sites, as well as Salt Creek sites, recorded EPT taxa, however, EPT were absent at all upper and lower Anglesea River sites. Overall, with nine of a possible 33 objectives met, the results are either the same when compared with 2021 for the sites BCT1, SC1 and W2/3 (2 objectives achieved among the 3 sites) (Ecology Australia 2021) or better than the 2018 results for all 11 sites (3 objectives achieved among the 11 sites) (Ecology Australia 2019). Individual sample results from each site are presented in section 3.7.

Table 7 Site macroinvertebrate indices result from all sites, combining the three edge samples taken (non-attainment of SEPP (W) objectives indicated by shading).

Index	BC1	BC2	BC3	BCT1	BCT2	SC1	UAR2	UAR1	W1	W2	W3	SEPP (W) objective*
# taxa	19	15	15	9	11	10	14	13	13	7	6	20
SIGNAL2	5.5	4.7	4.5	4.6	4.5	4.7	3.3	2.6	3.1	3.9	3.5	3.4
EPT	6	4	4	3	3	1	0	0	0	0	0	6*
EPTO	7	4	4	3	3	1	2	0	0	1	0	NA

*Indicates an objective that was sourced from the previous report (Ecology Australia 2021) because no applicable objective exists in the current SEPP (W).



a.



b.

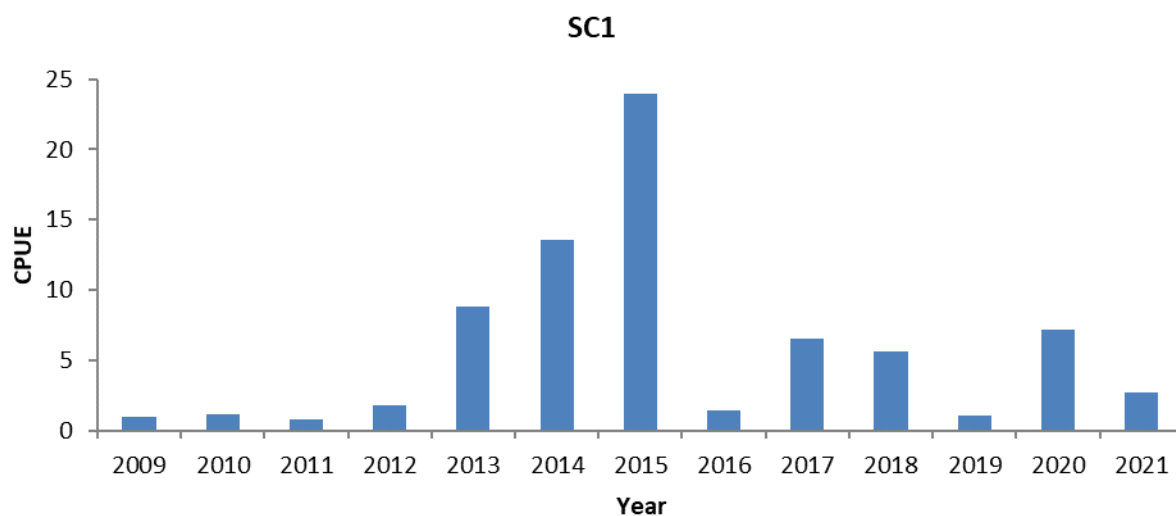
Figure 21 Site SC1 on 16 (a; flowing overbank) and 30 (b; water level receded) November 2021.

3.4 Southern Pygmy Perch

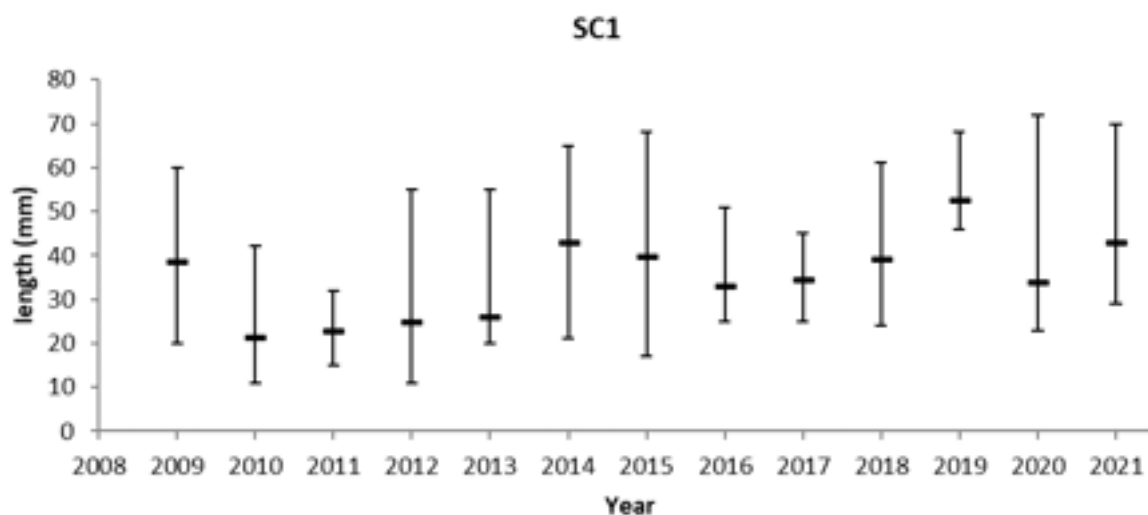
A total of 27 southern pygmy perch were captured from Salt Creek (SC1), and none were captured from Breakfast Creek tributary (Figure 22–Figure 24). The 2021 southern pygmy perch Catch Per Unit Effort (CPUE) from Salt Creek was substantially lower than recorded in 2020, but remains substantially higher than that detected in 2019. Young-of-year fish (i.e. fish considered to be less than one year of age) were detected at SC1, which indicates that fish are breeding and that juvenile fish are surviving. This is the second year in a row that young-of-year fish have been detected within Salt Creek. 2021 was the fourth consecutive year that southern pygmy perch were not recorded at the Breakfast Creek tributary site.



Figure 22 Southern pygmy perch from Salt Creek.



a) Fish Catch Per Unit Effort (CPUE; fish per trap) of southern pygmy perch at site SC1.



b) Mean (black bars), together with minimum and maximum lengths (TL) of southern pygmy perch.

Figure 23 Site SC1 Southern Pygmy Perch spring CPUE (a), and length (b) summary 2009–2021.

3.5 Otway Bush Yabby

Otway bush yabby *Geocharax tasmanicus* is a small freshwater crayfish listed as Endangered under the FFG Act 1988. Otway Bush Yabby was detected at two of the three surveys locations where the species has been detected annually since 2017 (Ecology Australia 2018–2020). In 2021, Otway bush yabby was detected at six of the 11 sites (the one in three-year macroinvertebrate sampling was undertaken in 2021) (Figure 24). Otway bush yabby was only detected in the bait traps in 2021 at SC1 with a total of nine being captured. This is a substantial reduction on the number captured in previous years, although it should be noted that RBA sampling is essentially a presence/absence sampling method.



Figure 24 Otway bush yabby from Breakfast Creek.

3.6 Water quality

Water quality results were consistent with results from previous years (GHD 2010–17, Ecology Australia 2018–2021; Table 8). It should be noted that water quality results are highly variable within short temporal periods, and that to assess against SEPP (W) indices, a minimum of 11 data points is required from a single year (i.e. to calculate annual percentiles). Thus, the SEPP (W) objectives are only able to be compared against the results to provide context. For all Breakfast Creek and tributary sites, SEPP (W) was potentially met for conductivity, but was only potentially met for dissolved oxygen at one of the five sites and pH at two sites. At the Salt Creek site, the SEPP (W) was potentially met for conductivity and dissolved oxygen, but not for pH. At the two upper Anglesea River sites, the SEPP (W) was potentially met for conductivity, but not for dissolved oxygen at the most downstream of these sites and not for pH at both sites. The lower Anglesea River wetland sites all failed to potentially meet any SEPP (W) objectives.

Table 8 In situ water quality results and SEPP (W) objectives (potential non-attainment of SEPP (W) objectives indicated by red shading).

Site	Temperature (°C)	Conductivity (µs/cm)	Dissolved oxygen mg/L	%Sat	pH
SEPP (W) objective		≤2000 (75 th percentile)		≥70 (25 th percentile)	6.8-8 (25 th -75 th percentile)
BC1	16.4	477	8.35	87.5	7.3
BC2	11.69	380	1.12	10.5	6.4
BC3	12.19	488	6.49	62.4	6.81
BCT1	11.5	245	2.1	19.9	4.85
BCT2	11.52	236	1.98	18	4.85
SC1	10.85	264	7.11	72	5.85
UAR1	13.85	121	8.66	86	6.43
UAR2	12.84	580	0.67	6.6	5.87
W1	13.46	2320	2.47	24.1	3.27
W2	14.45	3520	0	0	3.25
W3	15.09	3460	0	0	2.98

3.7 Aquatic monitoring sites

3.7.1 Breakfast Creek and tributaries



Figure 25 Breakfast creek in 2021, photo taken at the most downstream site BC3.

Breakfast creek (BC1–3) and its tributary (BCT1–2) consisted of a narrow, relatively shallow channel with a maximum width of 3.0 m at site BC2, and more typically was <1.5 m wide. The maximum depth of any site was ~0.75 m (site BC3). Flow characteristics at the sites were determined to be between no flow and moderate flow, with a greater proportion of no flow being recorded at BC1 (the most upstream site) and progressively increasing the proportion of slow and moderate flows as sites moved downstream, with BC3 having the most rapid flow. Only the most upstream site (BC1) was a series of pools along the length of the surveyed reach, with all other sites continuous. The substrate was predominantly silt/clay, with some sand, pebble and gravel present, except for the most upstream site BC1, where the majority of the site was bedrock. The main instream cover available for fish and macroinvertebrates, in decreasing order of prevalence, consisted of coarse particulate organic matter (e.g. leaves and other organic debris), overhanging terrestrial vegetation, loose silt lying on the surface, overhanging bank, woody debris, filamentous algae, roots, and moss.

All Breakfast Creek sites achieved the SEPP (W) objective for SIGNAL2 score (Table 9). No other objectives were achieved on a sample-by-sample basis. Despite the lower number of overall taxa, it is promising that EPT taxa were again detected at all Breakfast Creek and tributary sites and make up a good proportion of the taxa detected.

Table 9 Individual macroinvertebrate sample indices results for all Breakfast Creek and tributary sites, showing SEPP (W) objectives (shading indicates non-attainment of SEPP (W) objectives).

Index	BC1			BC2			BC3			BCT1			BCT2			SEPP (W)*
	E1	E2	E3	E1	E2	E3	E1	E2	E3	E1	E2	E3	E1	E2	E3	
# taxa	10	8	12	12	7	6	7	9	9	5	5	7	4	8	4	20
Abundance	100	122	187	85	78	42	99	104	80	14	12	15	10	21	28	NA
SIGNAL2	5.6	5.6	5.3	4.8	5.1	5	5.9	4	4.4	3.8	5.4	5.4	5.8	4.8	4.8	3.4
EPT	3	3	3	3	2	2	3	1	2	2	2	3	2	3	2	6*
EPTO	4	4	4	3	2	2	3	1	2	2	2	3	2	3	2	NA

*Indicates an objective that was sourced from the previous report (Ecology Australia 2021) because no applicable objective exists in the current SEPP (W).

No Southern Pygmy Perch were detected at BCT1 during this round of monitoring. This is the fourth year in a row that this species has not been detected at BCT1. Previous reports have highlighted that there may have been a recruitment failure at this site in 2017. Otway bush yabby were captured only in low abundance in 2021, with abundance being highest at site BCT1 and individuals ranging in size from 6–23 mm occipital carapace length (OCL) (Figure 26).

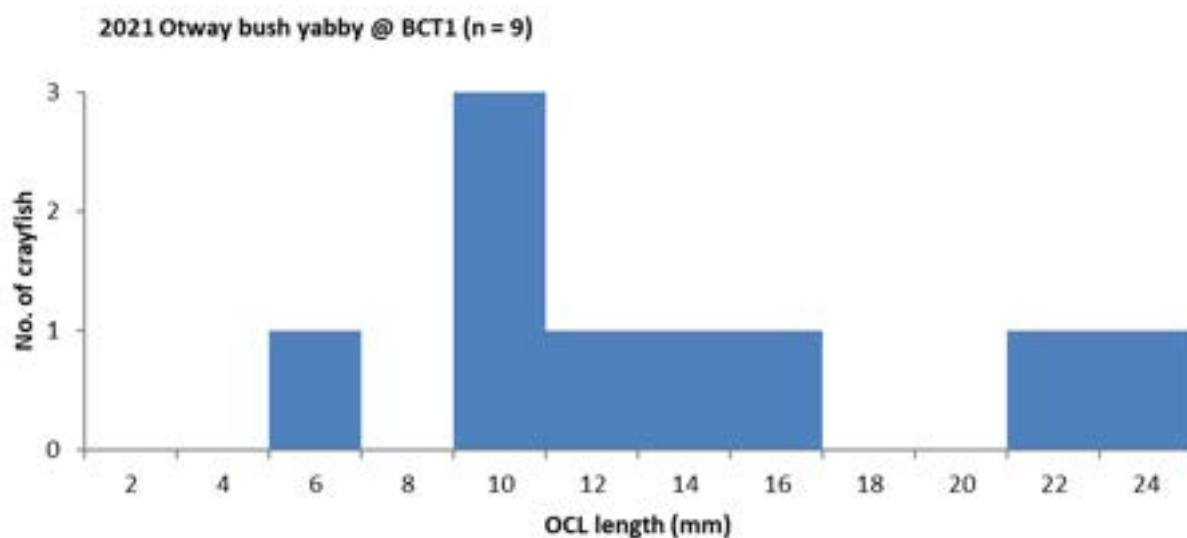


Figure 26 Length-frequency histogram for the 2021 Otway bush crayfish captured at Breakfast Creek site BCT1.

3.7.2 Salt Creek



Figure 27 Salt Creek in 2021 at site SC1.

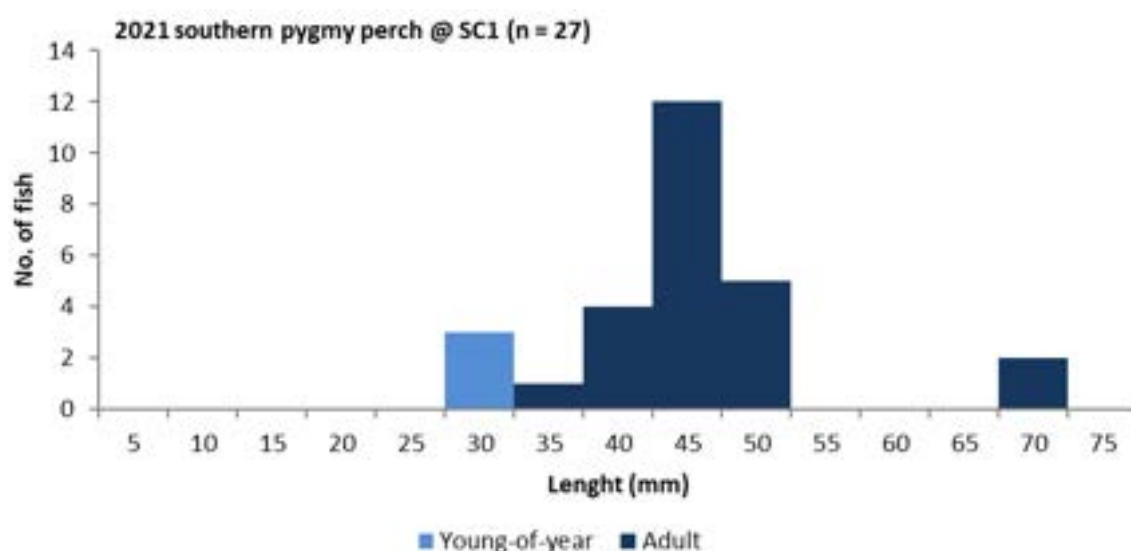
Salt Creek was sampled at one site, SC1, which of all the sites (aside from lower Anglesea River wetland 1) had the largest surface area of water and appears to be permanent. The substrate was silt/clay and there was water flowing into and out of the large pool. Despite the flow through the pool there were still sections of lentic (still) habitats. The main instream cover available for fish and macroinvertebrates, in decreasing order of prevalence, was Coarse Particulate Organic Matter (CPOM; e.g. leaves, branches and other organic debris), overhanging terrestrial vegetation, aquatic vegetation, overhanging bank and logs. The loose silt that has been dominant at this site in previous years was absent and likely flushed through with the high flows in 2021. The dominant aquatic vegetation taxa were *Juncus* spp. and *Carex* spp.

Salt Creek attained SEPP (W) objectives for SIGNAL score for all two of three edge samples, however, did not attain SEPP (W) goals for all other indices (Table 10). This result represents a slight decline for the Salt Creek site when compared with 2020 (Ecology Australia 2021). Otway bush yabby were not detected during the fish survey at Salt Creek; however, they were present in the macroinvertebrate survey samples in very low abundances. Although quantitative sampling methods were not used, this represents a potential decrease in abundance when compared with record high numbers detected in 2020 (Ecology Australia 2021).

Table 10 Individual macroinvertebrate sample results for Salt Creek, showing SEPP (W) objectives (shading indicates non-attainment of SEPP (W) objectives)

Index	SC1			SEPP (W) objective*
	E1	E2	E3	
# taxa	8	9	3	20
Abundance	29	51	6	-
SIGNAL2	5	4.3	3.7	3.4
EPT	1	0	0	6*
EPTO	1	0	0	-

The CPUE of southern pygmy perch at SC1 was about one third that of the previous year. The length frequency histogram again shows two cohorts, those larger and older fish, around 70 mm and those younger fish around 30–50 mm (Figure 28). This histogram and the results from 2020 indicate that recruitment has occurred for two consecutive years. Southern pygmy perch typically reach maturity at approximately 30–33 mm (Knight 2008) (conservatively set at 30 mm for the histogram). The smallest length detected were smaller than 30 mm, indicating that young of year fish are present within the system.

**Figure 28 Length-frequency histogram for the 2021 southern pygmy perch captured at Salt Creek site SC1.**

3.7.3 Lower Anglesea River Wetlands



Figure 29 Lower Anglesea River wetlands at site wetland 2 in 2021.

In 2021, Lower Anglesea River wetland 1 differed substantially from 2017 (Figure 30). The entire site at wetland 1 was inundated to the bank high water mark, and the depth averaged 0.5 m for the majority of the wetland, with a maximum depth of ~1.0 m. The substrate was predominantly clay/silt, with *Juncus* spp., paperbark and tea-tree throughout the site.



Figure 30 Lower Anglesea River Wetlands at site wetland 1 in 2018 (a) compared with 2021 (b).

Lower Anglesea River wetland 2 and 3 were similar in 2021, aside from the large, still pool (Figure 29), there was flow moving through both sites, more so in wetland 3 than 2. The large pool in wetland 2 was densely dominated by algae and *Triglochin* spp., which was the most abundant macrophyte at both wetland 2 and 3. The substrate was predominantly clay/silt, with a gravel track running adjacent to the site and presenting a potential point source of pollutants and sediment.

Lower Anglesea River wetland 3 was sampled separately in 2021 as a result of the wet winter/spring in 2021 and achieved SIGNAL 2 objectives for all three replicates. However, given the low number of taxa and absence of EPT taxa at this site, this result should be treated with caution (Table 11). No other objectives were achieved for any other lower Anglesea River wetland sites on a sample-by-sample basis despite the abundant macroinvertebrate assemblage at wetland site 3. These results are also difficult to compare with previous results, as the most recent results either combined wetland 2 and 3 (e.g. Ecology Australia 2021) and/or were unable to sample wetland 1 because it was dry (e.g. Ecology Australia 2019). No Otway bush yabby were detected at any of the Lower Anglesea River wetland sites (Note: they have not been previously detected at this site and were not expected in 2021).

Table 11 Individual macroinvertebrate sample results lower Anglesea River wetlands 1–3, showing SEPP (W) objectives (shading indicates non-attainment of SEPP (W) objectives)

Index	W1			W2			W3			SEPP (W) objective*
	E1	E2	E3	E1	E2	E3	E1	E2	E3	
# taxa	9	5	8	6	3	4	5	1	4	20
Abundance	136	124	125	19	49	30	39	23	15	NA
SIGNAL2	2.9	3.2	3.1	4	3.3	3.3	3.8	6	3.5	3.4
EPT	0	0	0	0	0	0	0	0	0	6*
EPTO	0	0	0	1	0	0	0	0	0	NA

*Indicates an objective that was sourced from the previous report (Ecology Australia 2021) because no applicable objective exists in the current SEPP (W).

3.7.4 Upper Anglesea River



Figure 31 Upper Anglesea River in 2021 at the most upstream site UAR1.

Both upper Anglesea River sites were flowing in 2021. The substrate was predominantly silt/clay, with some gravel and sand present (especially at UAR2). The main instream habitats providing habitat for macroinvertebrates were coarse particulate organic matter (especially leaf litter, but also small branches and branch piles), macrophytes, larger snags, trailing bank vegetation and overhanging banks. The loose silt described as dominating the cover in 2017 at these sites was absent in 2021, likely flushed through the river from the high flows in winter/spring 2021. The dominant aquatic vegetation types were submerged, or feather-like vegetation, *Triglochin* spp., *Carex* spp., an unknown grass-like submerged vegetation and *Myriophyllum* spp. Upper Anglesea River site 1 was immediately downstream of a road crossing, and Upper Anglesea River site 2 was immediately upstream of a road crossing and had numerous bike trails/tracks in the close vicinity, both likely to increase sedimentation of the river.

No Macroinvertebrate SEPP (W) objectives were met for any upper Anglesea River sites on a sample-by-sample basis (Table 12). This result indicates that these sites have potentially degraded slightly since they were last sampled in 2018 (where some SIGNAL based objectives were met) (Ecology Australia 2019). Otway bush yabby, however, was present in low abundances at both sites.

Table 12 Individual macroinvertebrate sample results upper Anglesea River sites, showing SEPP (W) objectives (shading indicates non-attainment of SEPP (W) objectives)

Index	UAR2			UAR1			SEPP (W) objective*
	E1	E2	E3	E1	E2	E3	
# taxa	7	7	9	5	7	6	20
Abundance	14	43	23	20	21	60	NA
SIGNAL2	2.9	3.3	2.9	3	2.3	2.7	3.4
EPT	0	0	0	0	0	0	6*
EPTO	0	0	2	0	0	0	NA

*Indicates an objective that was sourced from the previous report (Ecology Australia 2021) because no applicable objective exists in the current SEPP (W).

4 Discussion

4.1 Vegetation

In the Anglesea Swamp sites, overall species richness within the wetland communities (Aquatic Sedgeland EVC and Swamp Scrub EVC) showed little change from previous years and dominant species remained present at all sites. Since the revised MAP commenced, the total number of species has decreased across 5 of the 6 sites in the Anglesea Swamp. Partly, this reduction in species can be explained by a decrease in several species which are associated with drier vegetation of the Heathy Woodland and Swamp Scrub EVC interface. Site AS4 has displayed a reduction of several species which contribute very little cover to the overall transect and are not predictive of changes to either the Swamp Scrub EVC or the Aquatic Sedgeland EVC.

In the Anglesea Estuary sites, native species richness remained relatively stable at LAR1, 2 and 3 and the variation displayed is within expected ranges of annual variation. Site LAR4 has decreased in total number of species since the revised MAP commenced. The species which have dropped out of LAR4 all contributed to only 1 or 2 quadrats in total and their disappearance from the transect is unlikely due to hydrological changes. Weed species continue to be recorded in all Estuary sites except LAR4 (Appendix 2). Native plant species continue to be recorded in higher numbers and higher frequencies than weeds since monitoring in the estuary began (see Ecology Australia 2015, 2017, 2019 and 2020).

Overall, the frequency of aquatic functional groups has decreased across the Anglesea Swamp which is shown by the decrease in average frequency of the aquatic functional group across all sites between 2017 and 2019. Aquatic functional groups are highly sensitive to changes in hydrology as they require permanent water in their root zone to survive (Cassanova 2011 and Doeg et.al. 2012). The 2021 rainfall data from Aireys Inlet recorded average annual rainfall as 631 mm from 1994 to 2021 (BOM 2022). Both 2014 (498 mm) and 2015 (488 mm) were relatively dry years and little to no standing water was present across all sites (Ecology Australia 2014, Ecology Australia 2015). Following this was two years of above or near average rain fall in 2016 (714 mm) and 2017 (609 mm), during which time the Aquatic functional groups showed little change in abundance. By contrast, yearly rainfall decreased in 2019 to 525 mm and as a result, the Aquatic functional groups dropped approximately 20% across all sites. Whilst yearly rainfall across 2020 (713 mm) and 2021 (726 mm) was higher than average, the overall percentage of Aquatic functional groups remains lower than pre-2019 levels despite showing a slight increasing trend each year. This may be due to a lag time for vegetation to respond to increase water availability.

Across most Anglesea Swamp sites, aquatic functional group species, including southern bristle-sedge *Chorizandra australis*, fine twig-sedge *Machaerina arthropphylla* and the square twig-sedge *Machaerina tetragona* dropped in frequency after 2017 and have not yet returned to pre-2017 levels. The exception to this appears to be the common water-ribbons *Cycnogeton procerum* sp. aff. that appears to respond quickly to changes in available water and tends to increase in frequency after yearly rainfall increases.

Based on observations at two sites, it appears that several dominant species have died back in recent years (Appendix 6 and 7). This has occurred for the square twig-sedge at site AS2 and the fine twig-sedge, the tall rush and the spreading rope-rush at site AGP2_2014. The timing and cause of this die-back remains unclear. It is understood that these sites were dry in 2014 and were either dry or had only 3 cm of standing water recorded in only 2 quadrats in 2015 (Ecology Australia 2014, Ecology Australia 2015). Using the photo point data from 2014, neither site had the same extent of clearly dead

vegetation in 2014 or 2015 with AGP2_2014 showing many healthy flowering stems of tall rush. In the dominant species frequency data for AGP2_2014, the frequency of tall rush and the fine-twig sedge remain relatively stable until 2017 after which their frequency drops significantly. Similarly at AS2, the dominant square twig-sedge shows a drop in frequency after 2017. Both twig-sedges fit within the Aquatic functional group, which are most susceptible to changes in hydrology and not tolerant of long periods without water. The tall rush fits within the Amphibious fluctuation tolerator – emergent functional group which have more tolerance to changing water levels but require 8 – 12 months of the year to have water present. It is likely that the dry conditions of 2014 and 2015 initiated the die-back of these species, however there are other variables that can affect plant health such as soil and water salinity and acidity. Both the tall rush and the square twig-sedge appeared to show signs of recovery in 2021 with both species increasing in frequency at their respective sites, however this was not obvious in the field. Dead thickets had one or two resprouting live stems which allowed them to be scored as present despite the majority of the individual or stand being dead. This means while each species is still present and increasing in frequency, it clearly hasn't yet recovered to pre-die-off levels.

Algal mats continue to be recorded and have increased in one site in the Anglesea Swamp (first recorded in 2016). While algae are a normal part of wetland ecosystems, the growth of algae can also be associated with low flows (Mitrovic and Bowling 2013, Davie and Mitrovic 2014) and might suggest reduction of overbank flows in the swamp. At this stage, there are no obvious impacts on the vegetation.

4.1.1 Botanical recommendations

Recommendations regarding the vegetation monitoring component include:

- Addition of cover estimates of species in each quadrat along a transect following the Braun Blanquet cover abundance scale. Cover estimates allow trends to be detected at a finer scale compared to presence and absence scores alone. This will allow the MAP to detect changes in vegetation before species decline significantly and be able to track the trajectory of species which appear to have significantly declined in sites AS1 and AGP2_2014.
- Consider as part of the Bulk Entitlement review process using GIS to analyse and detect largescale changes in vegetation across the Anglesea swamp and estuary. This could be approached by analysing the percentage cover and change over time of the dominant Swamp Scrub EVC and Aquatic Sedgeland EVC (or representative dominant species). Dominant components of each EVC or key species could be differentiated using colour (aerial, satellite or drone), reflectance properties of vegetation (satellite) or heights using LIDAR. This may allow changes in extent of dominant species such as the scented paperbark *Melaleuca squarrosa* to be detected at the scale of the whole swamp. This was attempted this year across selected Anglesea Monitoring sites however, the differences in resolution and colour of available imagery provided unmeaningful results. Despite this, the method used was successful enough at identifying vegetation types and it is believed that with appropriate imagery, this could be a valuable tool to detect largescale changes in vegetation.

4.2 Frogs

Results of the 2021 frog surveys as part of the Anglesea MAP are consistent with previous years, with low numbers and diversity of frogs recorded across both the Anglesea Swamp and Anglesea Estuary

(Table 6, Figure 29). Frogs were heard within 100m of the study sites in all 4 of the estuary sites, but only at half of the swamp sites. However, at the swamp sites, with the exception of AS6, frogs were heard calling more than 100m away from the sites suggesting frogs occur in the greater swamp area. The low recorded species richness and abundance of frog is likely correlated with the quality of frog habitat in the study area, with the recorded species the more ubiquitous species found in Victoria.

The persistence of frog populations depends on the ability of individual species to produce subsequent generations that will be able to themselves reproduce the following generation of individuals. The ability of frogs to successfully reproduce depends on the availability of suitable aquatic habitat at the breeding site. One of the key requirements for successful breeding in frogs is the hydroperiod. Although the hydroperiod will vary between species, adequate water needs to be available for long enough to raise the next generation to maturity. For instance, southern bullfrog tadpoles typically require a period for development of up to six months to reach maturity. Hence, this species needs standing water for more than half a year for successful reproduction (Anstis 2013). The decrease in water level observed at the swamp site is likely to have impacted the southern bullfrog this season. Conversely, common eastern froglet tadpoles can reach maturity in only four to six weeks, and as a result can survive in small, highly intermittent waterbodies with less stable conditions (Lane and Mahony 2002; Hazell et al. 2003; Anstis 2013). This makes this species less susceptible to water level changes as successful breeding can be completed before the water dries completely.

During the 2021 surveys water depth changed significantly between the two surveys, to the extent that sites were either dry or were very shallow. The number of frogs heard calling from the site as opposed to frogs heard > 300m away, suggests the sites where call surveys were undertaken were no longer suitable to sustain frogs.

In addition to the physical water availability, water quality changes can occur because of changes in water level. Besides temperature, pH and salinity are two parameters that can significantly affect successful reproduction. For instance, acidic water can negatively impact the survival and growth of both frog eggs and developing tadpoles. Striped marsh frog eggs experience 100% mortality at pH below 4.0 (Barth and Wilson 2010). Across the swamp sites, pH was below 4 at all sites. This may have affected the reproductive effort of the related brown tree frog.

Similarly, the survival of southern brown tree frogs declined in elevated saline conditions (Chinathamby et al. 2006), with lower numbers of southern bullfrogs recorded in stormwater ponds with elevated salinity (Hamer et al. 2012). High saline levels may negatively impact adult frog populations, making them more prone to desiccation.

Detection of frogs is closely linked to antecedent weather conditions. Climatic occurrences such as rainfall can induce frog calling particularly near or in the breeding season. Should monitoring occur in less favourable calling times, species richness and abundance could be missed. Possibly the use of audio recorders could improve the chance of capturing frog calls. Audio analysis can be time consuming but can provide a longer seasonal dataset.

Much of the discussion above is linked to aquatic habitat parameters – things like water quality, seasonality of water in wetlands or temperature. More detailed surveys of water quality parameters, including water depth and seasonality. These are the parts of the habitat that can potentially be manipulated to provide conditions for improved frog populations.

4.2.1 Comparisons with citizen science in 2021

In 2021 there was a strong local community interest in changes in the frog population in the Coogoorah park wetland near the Anglesea wetland frog monitoring sites. Barwon Water provided Ecology Australia with information from the local community and citizen science groups which suggested a general decline in the frog population in the Coogoorah park wetland.

These findings were noted by the citizen science group following observations of a significant decline in the chorus of frogs compared to that of previous years at the Coogoorah park wetland. However, those parts of the Coogoorah park wetland surveyed by the citizen science group differs from those areas surveyed under the MAP and are predominantly fed by localised stormwater runoff and not the perched water table. As such, due to differences in water quality between the sites examined by the citizen scientists and Ecology Australia, a difference in frog calling behaviour is unsurprising.

Further, while the citizen science observations do differ from those of the Ecology Australia monitoring, the annual monitoring conducted by Ecology Australia has changed little over the past few years, suggesting the frog populations within the MAP monitoring area has not changed substantially from previous years. The information provided by the citizen science group could be used to better understand the frog population dynamics within the greater Anglesea region and could potentially be used as an external reference to compare the frog population within the MAP area. Further, based on the citizen science groups findings we would recommend that relevant management groups for the Coogoorah park wetland area undertake frog monitoring to gain a better understanding of the frog population to determine if there has been a decline and the extent of any decline in this area.

4.3 Aquatic Ecology

The macroinvertebrate monitoring results were relatively consistent with previous years. The Breakfast Creek and tributary sites appear to have marginally improved and the upper Anglesea River sites appear to have marginally declined (C.f. Ecology Australia 2019, 2021). The water levels at all sites were significantly higher in 2021 compared with the previous triennial survey in 2018, with all 11 sites containing sufficient water levels for sampling (wetland 1 was dry in 2018 and wetland 2 and 3 were combined due to low surface water). The Breakfast Creek and wetland 1 sites, which were extensively inundated in 2021, recorded macroinvertebrate abundances and richness similar or higher than those detected in 2018. This suggests that Breakfast Creek has maintained its macroinvertebrate community since the previous triennial surveys. Additionally, it suggests that wetland 1, (which was dry in 2018) has recovered well from the drying, and that the macroinvertebrate community of all other sites have marginally declined. Another factor to consider is the dilution effect from the very wet winter/spring which may have both flushed and diluted the macroinvertebrate assemblage. Habitat was also much more readily available and connected in 2021 compared with 2020 (BCT1, SC1 and W2/3) and 2018 (all other sites). If conditions within the Anglesea catchment remain wet as they were in 2021, we would expect that by 2024 (when the next triennial survey is required to be completed as per the MAP, (Victorian Government, 2014), the macroinvertebrate community within the catchment would have improved.

Southern pygmy perch abundance (CPUE) at site SC1 was considerably lower than in 2020 but remains well above the record low of 2019. This could be due to a reduction in population size, but is more likely a result of dilution (i.e. reduced density) as the water levels and extent of inundated habitat at SC1 were considerably higher in 2021, meaning that the southern pygmy perch population had a greatly increased

area of habitat to utilise. The 2021 southern pygmy perch catch included young-of-year and juvenile fish, indicating that this population is continuing to breed in Salt Creek. This is the second year in a row where young-of-year and juvenile fish were detected. Conversely, this was the fourth year in a row that no southern pygmy perch have been detected at BCT1. This result indicates that the Breakfast Creek southern pygmy perch population formerly located in the vicinity of site BCT1 has likely become locally extirpated. A small hope for this population is that it has previously 'reappeared' after several years of no recruitment (GHD 2013–2015). This suggests that the site surveyed is not the Breakfast Creek 'source population'. Previous extirpation and subsequent re-colonisation from a nearby source population have occurred, however, the present 'disappearance' period at this site (2018–2021) is a much longer period than the previous one. The persistence of suitable habitat within drought refuge pools is expected to be the key to ensuring the persistence of source populations. We recommend additional effort occur to determine the ongoing existence of the southern pygmy perch in the Breakfast Creek catchment. Given the population of southern pygmy perch in the Anglesea catchment is genetically distinct (Cesar 2012), it is important to maintain populations within both Salt Creek and Breakfast Creek. Identification and monitoring of source population sites should, therefore, form an important component of the monitoring program for future years.

Otway bush yabby abundances appeared to be considerably lower in 2021 compared with 2020, however it should be noted that opportunistic detections during RBA sampling are likely not a reliable indication of abundance. As with the southern pygmy perch, the lower CPUE is most likely due to density related reductions in capture efficiency as a result increased water levels and more extensive available habitat for dispersal following a wetter than average winter/spring in 2021. All sites where Otway bush yabby were detected in 2021 were flowing and suitable habitat was abundant. Small, young-of-year/juvenile, individuals were detected in 2021, indicating this species is continuing to recruit. This species can complete its life cycle in both permanent and more intermittent habitats and the 2021 conditions provide the species with dispersal opportunities, which may lead to larger and more widespread populations in future years. Low pH levels (< 3.5), particularly within the lower Anglesea River wetlands, may inhibit the spread of Otway bush yabby within the Anglesea catchment, however, Otway bush yabby was detected in areas of lower pH (as low as 4.85 in this present year and 4.2 in 2020; Ecology Australia 2020) hinting that the Anglesea catchment population may be adapting to lower pH conditions. The pH conditions within the lower Anglesea River wetland sites have also improved compared with previous years and continuing improvements may lead to pH becoming suitable for Otway bush yabby in coming years. However, the increased connectivity and available habitat may also result in recolonisation of fish (potentially including eels), which could have a detrimental effect on the Otway bush yabby population.

4.3.1 Aquatic ecology recommendations

Recommendations regarding the aquatic monitoring component were proposed after the 2018 monitoring event (Ecology Australia 2019). These recommendations remain current and are reproduced and expanded upon following the 2021 event below:

- It may be beneficial to reduce the number of macroinvertebrate samples per site from three down to two, as the new SEPP (W) indices for macroinvertebrates are based on single samples, there is greater importance in collecting higher quality individual samples. The trade-off of this approach in terms of reduced replication and reduced data compatibility also

requires consideration. The suitability of this change being made permanent would best be considered as part of a review of the MAP.

- Given the recent failures to detect southern pygmy perch at BCT1, it would be beneficial to survey additional/alternative locations on Breakfast Creek to establish if a population persists. In addition, it would be beneficial to reassess the catchment as a whole for additional populations. This has not been done since 2012 and would ideally focus on historic records from Anglesea River and associated wetlands and Breakfast Creek, identification of refuge pools in the Breakfast Creek catchment, and investigation of known refuge pools throughout Salt Creek and Anglesea River (as identified in GHD 2010). As a genetically distinct population in an isolated catchment, it is of concern that the species may have retracted to a single remnant population. This results in a high level of vulnerability for this genetic lineage. This assessment can be undertaken at any time but would ideally be undertaken in late summer/autumn in terms of maximising capture rates.
- Otway bush yabby has been an informal target species for this project since 2019. It is recommended that Otway bush yabby be formalised as an additional target species within the MAP during the next review. The Otway bush yabby population has shown signs of stability and growth since 2019. While the present study detected Otway bush yabby in low abundance, their presence/absence at all triennial macroinvertebrate survey sites was recorded during the survey and effort should be made to continue detection of these species at all of these sites in the future. This effort should further be expanded by including this species in any expanded southern pygmy perch catchment scale assessment, as the survey methodology would be identical (i.e. bait traps) and cost-effective. Increased effort should provide a better understanding of the population size, distribution and demographics.

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Appendix 1 Anglesea Borefield, terrestrial ecology, Monitoring and Assessment Program, Anglesea Swamp, native plant species and Functional Groups (native plant species only) spring 2021

Status	Scientific name	Common name	Functional group	AGP2_2014	AS1_2014	AS2	AS3	AS4	ASP7_2014
	<i>Banksia marginata</i>	silver banksia	Tdr			✓		✓	
	<i>Cassytha glabella</i>	slender dodder-laurel	Tdr		✓		✓	✓	✓
	<i>Cassytha pubescens</i>	downy dodder-laurel	Tdr			✓			
	<i>Chorizandra australis</i>	southern bristle-sedge	Se			✓			✓
P	<i>Cryptostylis subulata</i>	large tongue-orchid	Se			✓			
	<i>Cynogeton procerum</i> sp. aff.	common water-ribbons	Se	✓	✓	✓		✓	✓
	<i>Eleocharis sphacelata</i>	tall spike-sedge	Se		✓				
	<i>Empodisma minus</i>	spreading rope-rush	Ate		✓		✓	✓	✓
P	<i>Epacris obtusifolia</i>	blunt-leaf heath	Atw				✓	✓	✓
vu	<i>Eucalyptus falciformis</i>	western peppermint	Tdr			✓			
	<i>Gahnia radula</i>	thatch saw-sedge	Tdr			✓			
	<i>Gahnia sieberiana</i>	red-fruit saw-sedge	Ate	✓		✓		✓	✓
P	<i>Gleichenia dicarpa</i>	pouched coral-fern	Ate		✓		✓	✓	✓
	<i>Isolepis inundata</i>	swamp club-sedge	Atl		✓				
	<i>Juncus procerus</i>	tall rush	Ate	✓					
	<i>Lepidosperma longitudinale</i>	pithy sword-sedge	Ate					✓	✓
	<i>Leptospermum lanigerum</i>	woolly tea-tree	Atw					0	✓
	<i>Leptospermum</i> spp.	tea-tree	T	✓	✓	✓	✓	✓	✓
	<i>Machaerina arthropphylla</i>	fine twig-sedge	Se	✓	✓			✓	✓
	<i>Machaerina juncea</i>	bare twig-sedge	Ate		✓				✓
	<i>Machaerina tetragona</i>	square twig-sedge	Se			✓	✓	✓	
P	<i>Melaleuca squarrosa</i>	scented paperbark	Atw	✓	✓	✓	✓	✓	✓
	<i>Opercularia varia</i>	variable stinkweed	Tdr			✓			
	<i>Platylobium obtusangulum</i>	common flat-pea	Tdr			✓			

Status	Scientific name	Common name	Functional group	AGP2_2014	AS1_2014	AS2	AS3	AS4	ASP7_2014
	<i>Pteridium esculentum</i> subsp. <i>esculentum</i>	austral bracken	Tdr		✓	✓			
	<i>Rhynchospora procumbens</i>	whitemarianth	Tdr			✓			
	<i>Schoenus brevifolius</i>	zig-zag bog-sedge	Atw		✓	✓	✓	✓	✓
P	<i>Sprengelia incarnata</i>	pink swamp-heath	Ate				✓	✓	
	<i>Xyris operculata</i>	tall yellow-eye	Ate				✓		✓
Number of species per site				6	12	16	10	14	15
Total number of species				29					

Appendix 2 Anglesea Borefield, terrestrial ecology, Monitoring and Assessment Program,
Anglesea Estuary, plant species and Functional Groups (native plant species only)
spring 2021

Status	Scientific name	Common name	Functional group	LAR1	LAR2	LAR3	LAR4
#	<i>Acacia longifolia</i> subsp. <i>longifolia</i>	sallow wattle	NA	☐	☐	✓	☐
#	<i>Acacia longifolia</i> subsp. <i>sophorae</i>	coast wattle	NA	✓	☐	☐	☐
*	<i>Aira elegantissima</i>	delicate hair-grass	NA	☐	☐	✓	☐
*	<i>Anthoxanthum odoratum</i>	sweet vernal-grass	NA	☐	☐	✓	☐
	<i>Cycnogeton procerum</i> sp. aff.	common water-ribbons	Se	✓	✓	✓	✓
*	<i>Erigeron</i> sp.	fleabane	NA	☐	☐	✓	☐
	<i>Eucalyptus ovata</i> subsp. <i>ovata</i>	swamp gum	Tda	✓	☐	✓	☐
	<i>Ficinia nodosa</i>	knobby club-sedge	Tdr	☐	☐	✓	☐
	<i>Gahnia sieberiana</i>	red-fruit saw-sedge	Ate	✓	☐	☐	☐
*	<i>Gladiolus</i> sp.	gladiolus	NA	☐	☐	✓	☐
	<i>Goodenia ovata</i>	hop goodenia	Tdr	✓	✓	✓	☐
	<i>Goodenia radicans</i>	shiny swamp-mat	Arp	☐	✓	✓	✓
*	<i>Holcus lanatus</i>	Yorkshire fog	NA	✓	☐	✓	☐
	<i>Isolepis inundata</i>	swamp club-sedge	Atl	✓	☐	☐	☐
	<i>Juncus kraussii</i> subsp. <i>australiensis</i>	sea rush	Se	✓	✓	✓	✓
	<i>Lachnagrostis filiformis</i>	common blown-grass	Tdr	☐	✓	☐	☐
	<i>Leptinella longipes</i>	coast cotula	Arp	☐	✓	✓	✓
	<i>Leptospermum scoparium</i>	manuka	Tda	✓	✓	☐	☐
	<i>Leptospermum</i> sp.	tea-tree	NA	☐	☐	✓	☐
	<i>Lobelia anceps</i>	angled lobelia	Ate	✓	✓	✓	✓
	<i>Myoporum insulare</i>	common boobialla	Tda	☐	✓	☐	☐
	<i>Phragmites australis</i>	common reed	Arp	✓	✓	✓	☐
*	<i>Plantago coronopus</i>	buck's-horn plantain	NA	☐	☐	✓	☐
	<i>Poa poiformis</i> var. <i>poiformis</i>	coast tussock-grass	Tdr	☐	✓	✓	✓
	<i>Senecio glomeratus</i>	annual fireweed	Tdr	☐	✓	✓	☐
*	<i>Symphyotrichum subulatum</i>	aster-weed	NA	☐	✓	☐	☐
*	<i>Vulpia bromoides</i>	squirrel-tail fescue	NA	☐	☐	✓	☐
Number of species per site				11	13	20	6
Total number of species				27			

Appendix 3 Results by sample, including genus where identified, for the Breakfast Creek and tributary sites sampled in 2021 (E1 = Edge sample 1, E2 = Edge sample 2 and E3 = Edge sample 3, T = Total per site).

Taxa		BC1				BC2				BC3				BCT1				BCT2			
Family/sub-family	Genus	E1	E2	E3	T	E1	E2	E3	T	E1	E2	E3	T	E1	E2	E3	T	E1	E2	E3	T
Acarina	sp.			1	1											1	1				
Carabidae	sp.										1		1								
Ceratopogonidae	sp.			1	1																
Chironomidae	sp.															1	1				
Chironominae	sp.	5	10		15	1			1			2	2		4				6	3	9
Culicidae	sp.										1		1	3			3				
Curculionidae	sp.																		1		1
Diptera	sp.																		1		1
Dixidae	sp.			1	1																
Dytiscidae	sp.	8	3	11	22	5	9	3	17	10	7	2	17	1			1			1	1
Elmidae	sp.					1			1												
Gripopterygidae	<i>leptoperla</i>									2			2		3	3	3	6	6	13	25
Hydrobiosidae	<i>Taschorema</i> complex	1			1					1			1		1				1		1
Hydrochidae	sp.			1	1	1			1												
Hydrophilidae	sp.			1	1						1		1								
Janiridae	sp.							1	1					5		3	8	1			1
Koonungidae	sp.					1			1												
Leptoceridae	<i>Leptorussa</i>					1			1			2	2								
Leptoceridae	<i>Tripletidina</i>			2	2																
Leptoceridae	<i>Tripletides</i>	44	39	27	110	1		1	2					3		2	5	1	2	8	11
Leptoceridae	sp.			103	103																
Leptophlebiidae	<i>Atalopplebia</i>		1		1																
Leptophlebiidae	<i>Nebiosphlebia</i>		56		56																
Leptophlebiidae	<i>Nousia</i>			30	30	54		23	77	78	74	56	208								
Leptophlebiidae	sp.	32			32		49		49												
Oligochaeta	sp.						2		2			2	2								
Orthocladinae	sp.			1	1							2	2								
Polycentropodidae	<i>Neurecipsis</i>													1		1	2				
Scirtidae	sp.	5		3	8	15	11	9	35	2	10	9	21					1			1
Simuliidae	sp.	1	4		5	1	1	2	4	2	3	1	6		1	1	1		1		1
Tanypodinae	sp.	1	4		5	2			2	3	4	1	8								
Telephlebiidae	<i>Austrochna</i>	1	3		4																
Telephlebiidae	sp.			2	2																
Tipulidae	sp.	1			1	1	2		3		1		1								
Trichoptera	sp.						2		2												
Veliidae	sp.														1				1		1
Total		99	120	184	403	84	76	39	199	98	102	77	277	13	10	12	25	9	19	25	53

Appendix 4 Results by sample, including genus where identified, including genus identifications where possible, for the Salt Creek and upper Anglesea River sites sampled in 2021 (E1 = Edge sample 1, E2 = Edge sample 2 and E3 = Edge sample 3, T = Total per site).

Taxa		SC1				UAR2				UAR1			
Family/sub-family	Genus	E1	E2	E3	T	E1	E2	E3	T	E1	E2	E3	T
<i>Acarina</i>	sp.	2	1	1	4								
<i>Carabidae</i>	sp.									1	2		3
<i>Ceinidae</i>	sp.					1		1	2			7	7
<i>Chironomidae</i>	sp.									15	9		24
<i>Chironominae</i>	sp.					2	3	1	6			3	3
<i>Culicidae</i>	sp.						1		1		1		1
<i>Dolichopodidae</i>	sp.									1	1		2
<i>Dugesidae</i>	sp.											1	1
<i>Dytiscidae</i>	sp.	1	21	1	23		11	5	16	1	2	24	27
<i>Elmidae</i>	sp.					1	1		2				
<i>Eusiridae</i>	sp.	5	4		9		12		12				
<i>Glacidorbidae</i>	sp.		1		1								
<i>Hydrochidae</i>	sp.	1	5		6			3	3	1			1
<i>Hydrophilidae</i>	sp.					1		2	3		2		2
<i>Koonungidae</i>	sp.					3	12	3	18				
<i>Lepidoptera</i>	sp.		1		1								
<i>Leptophlebiidae</i>	sp.	3			3								
<i>Lestidae</i>	sp.							1	1				
<i>Notonectidae</i>	sp.					1			1			1	1
<i>Oligochaeta</i>	sp.										2		2
<i>Paramelitidae</i>	sp.					4			4				
<i>Planorbidae</i>	sp.						1	3	4				
<i>Scirtidae</i>	sp.	8	4		12							21	21
<i>Tanypodinae</i>	sp.	1	1		2								
<i>Telephlebiidae</i>	<i>Austrochna</i>							1	1				
<i>Veliidae</i>	sp.	7	11	1	19								
Total		28	49	3	80	13	41	20	74	19	19	57	95

Appendix 5 Results by sample for the lower Anglesea River wetland sites sampled in 2021 (E1 = Edge sample 1, E2 = Edge sample 2 and E3 = Edge sample 3, T = Total per site).

Taxa		W1				W2				W3			
Family/sub-family	Genus	E1	E2	E3	T	E1	E2	E3	T	E1	E2	E3	T
<i>Acarina</i>	sp.			1	1								
<i>Ceratopogonidae</i>	sp.	1	2		3	2			2				
<i>Chironomidae</i>	sp.	19	25		44	1	10	3	14				
<i>Corixidae</i>	sp.	43	51	67	161								
<i>Culicidae</i>	sp.	55	39	25	119	5	7	1	13	4		4	8
<i>Curculionidae</i>	sp.			1	1								
<i>Dytiscidae</i>	sp.	4		15	19								
<i>Elmidae</i>	sp.					1			1				
<i>Hydraenidae</i>	sp.							1	1				
<i>Hydrochidae</i>	sp.									1			1
<i>Hydrophilidae</i>	sp.											1	1
<i>Hygrobidae</i>	sp.			1	1								
<i>Nanophyidae</i>	sp.									1			1
<i>Noteridae</i>	sp.	1			1								
<i>Notonectidae</i>	sp.	1			1								
<i>Odonata</i>	sp.					1			1				
<i>Scirtidae</i>	sp.	10	5	2	17	8	30	22	60	31	21	6	58
<i>Tipulidae</i>	sp.			10	10					1		1	2
<i>Veliidae</i>	sp.	1			1								
Total		135	122	122	379	18	47	27	92	38	21	12	71

Appendix 6 Examples of plant species die back at site AGP2_2014 including A. fine twig—sedge *Machaerina arthropylla*, B tall rush *Juncus procerus* and C. spreading rope-rush *Empodisma minus*.

A.



B.



C.



Appendix 7 Dead patches of square twig-sedge *Machaerina tetragona* at site AS2





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Anglesea Borefield Ecological Monitoring and Assessment Program 2020



Prepared for: Barwon Water

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Summary

Introduction

Barwon Water is permitted to extract groundwater from the Anglesea Borefield, under the Bulk Entitlement (Anglesea Groundwater) 2009 (BE), to supplement the water supply to Geelong and surrounding areas when required (Victorian Government 2009). The BE requires data to be collected to monitor the impacts of water drawdown under a Monitoring and Assessment Program (MAP) established in 2009.

Per the updated MAP (revised in 2014; Victorian Government 2014), Ecology Australia was commissioned to undertake both the aquatic and terrestrial ecological monitoring in 2020. The terrestrial monitoring, which is typically biennial and last conducted in 2019, was required again in 2020 as the borefield was operated in 2020 triggering the requirement for the terrestrial monitoring. Ecology Australia has undertaken terrestrial monitoring (vegetation and frogs) since 2009 and aquatic monitoring since 2017.

Methods

Vegetation monitoring was undertaken along six permanent transects in the Anglesea Swamp and four permanent transects in the Anglesea Estuary. The data collected included:

- Plant species presence;
- Ecological Vegetation Class (EVC);
- Plant Functional Group (FG);
- Bare ground cover; and
- Water depth (in the swamp only).

Frog survey data were collected at eight sites in the Anglesea Swamp and four sites in the Anglesea Estuary and included:

- Species richness;
- Abundance;
- Water quality; and
- Habitat attributes.

Aquatic monitoring consisted of a targeted survey for Southern Pygmy Perch and Otway Bush Yabby at two sites and macroinvertebrate sampling at three sites. Fish and macroinvertebrate monitoring included:

- Taxonomic diversity (macroinvertebrates);
- Abundance;
- Biometrics (fish);
- Water quality; and
- Habitat attributes.

Findings

Vegetation

Ecological Vegetation Classes, functional groups and species richness at each site have remained largely unchanged in the Anglesea swamp and Anglesea estuary. The frequency of dominant species in the Anglesea Estuary remains similar to previous years. Within four of the Anglesea Swamp sites, several dominant species from the aquatic (Se) and amphibious (Ate) functional group are beginning to show trends of decline in frequency.

Standing water remains present at all the swamp sites. Algal mats were again recorded at three swamp sites where they have been present since 2016. The abundance of these mats appears to be stable.

Bare ground cover across years is highly variable mostly due to changes in seasonal water height variation rather than other variables such as increased soil disturbance. Where vehicle disturbance was noted at site ASP7_2014 the tracks are still evident however the vegetation appears to be recovering.

Frogs

No frogs were recorded at any of the Anglesea Swamp survey sites during either survey. However, Southern Brown Tree Frogs *Litoria ewingii* and/or Southern Bullfrogs *Limnodynastes dumerilii* were calling at least 100 m from four of the eight Anglesea Swamp sites. Two Common Froglets *Crinia signifera* were heard at one site during the diurnal habitat survey. All four estuary sites had Southern Brown Tree Frogs and Southern Bullfrogs calling at least 100 m away and Southern Bullfrogs were present at two sites. The 2020 results are consistent with previous surveys, where low numbers and low diversity of frogs have been recorded across the survey sites.

Southern Pygmy Perch & Otway Bush Yabby

Southern Pygmy Perch were detected from one of the two monitoring sites, SC1, which is consistent with the results of the most recent survey. Recruitment was detected at site SC1, which indicates that fish are continuing to recruit within this system, despite a lack of recruitment evident in 2019. This year's sampling (2020) was the third consecutive year that Southern Pygmy Perch were not recorded at the BCT1. Based on this result it would be advisable to determine if there is a source population elsewhere in the Breakfast Creek catchment as the population at BCT1 appears to be locally extirpated.

Otway Bush Yabby was recorded at both SC1 and BCT1. This species has been detected at these sites annually since 2017 (Ecology Australia 2018–2020). The population of this species appears to be increasing with nearly three times as many Otway Bush Yabby captured in 2020 compared with 2019.

Macroinvertebrates

Macroinvertebrate community indices comparison against State Environmental Protection Policy – Waters objective (SEPP (W); Vic. Gov. 2018) was overall poor and typically consistent with previous surveys. Overall, only two of the possible 12 objectives were met during the 2020 macroinvertebrate monitoring, both for SIGNAL2 score, at sites SC1 and BCT1.

1 Introduction

Barwon Water is permitted to extract groundwater from the Anglesea Borefield, under the *Bulk Entitlement (Anglesea Groundwater) 2009* (BE), to supplement the water supply to Geelong and surrounding areas when required (Victorian Government 2009). Groundwater pumping under the BE is permitted as long as it does not adversely affect environmental values and groundwater-dependent ecosystems in the Jan Juc Groundwater Management Area.

The BE requires data to be collected to monitor the impacts of water drawdown. At the commencement of the BE, a Monitoring and Assessment Program (MAP) was developed. The MAP has been revised and updated once, in September 2014 under the *Bulk Entitlement (Anglesea Groundwater) 2014* (henceforth to be referred to as the “BE” succeeding the previous version; Victorian Government 2014). The MAP includes groundwater and surface water monitoring, acid sulfate investigations, land-level surveying and aquatic and terrestrial ecological monitoring (Victorian Government 2014).

Ecology Australia has undertaken the terrestrial (vegetation and frogs) monitoring component of the MAP since 2009 and the aquatic component (fish and macroinvertebrates) since 2017 (Ecology Australia 2009–2017).

The current MAP requires aquatic ecological monitoring to be undertaken annually, and terrestrial ecological monitoring to be undertaken biennially in the absence of groundwater pumping, and annually during periods of groundwater extraction (Victorian Government 2014). Barwon Water operated the borefield between August 2019 and June 2020 with a total of 2177.3 ML extracted from the borefield during operation (Barwon Water, 2021). As borefield extraction occurred during 2020 (i.e. during this present reporting period) the MAP requirement for terrestrial ecological monitoring was triggered (this would not have been required in 2020 if the borefield was not operated).

The 2020 ecological monitoring includes the Aquatic Ecology and Terrestrial Ecology components as detailed below.

1.1 Aquatic Ecology

The Aquatic Ecological monitoring component included spring monitoring of macroinvertebrates at three sites:

- Breakfast Creek tributary (BCT1);
- Salt Creek (SC1); and
- Lower Anglesea River wetland (Wetland 3).

Additionally, this component included spring sampling of Southern Pygmy Perch *Nannoperca australis* and Otway Bush Yabby *Geocherax tasmanicus* (formerly *Geocharax gracilis*) at two sites:

- Breakfast Creek tributary (BCT1); and
- Salt Creek (SC1).

1.2 Terrestrial Ecology

The Terrestrial Ecological monitoring component included spring monitoring of vegetation along established transects at six sites and frog monitoring at eight sites in the Anglesea Swamp (Figure 1):

- AS1_2014 (vegetation and frog monitoring);
- AS2 (vegetation and frog monitoring);
- AS3 (vegetation and frog monitoring);
- AS4 (vegetation and frog monitoring);
- AS5 (frog monitoring only);
- AS6 (frog monitoring only);
- ASP7_2014 (vegetation and frog monitoring); and
- AGP2_2014 (vegetation and frog monitoring).

Additionally, spring monitoring of vegetation was undertaken at established transects at four sites and frog monitoring was undertaken at the same sites in the Anglesea Estuary

- LAR1;
- LAR2;
- LAR3; and
- LAR4.

Vegetation data collection included: floristic species lists, Ecological Vegetation Classes (EVCs), plant Functional Groups, and other structural attributes (water depth, bare ground and algal mats).

The frog monitoring data collection included: species richness, abundance, water quality, and habitat attributes.

This report presents the monitoring methods and results, along with a discussion including a comparison of the 2020 data with annual data collected since the MAP review and update in 2014.

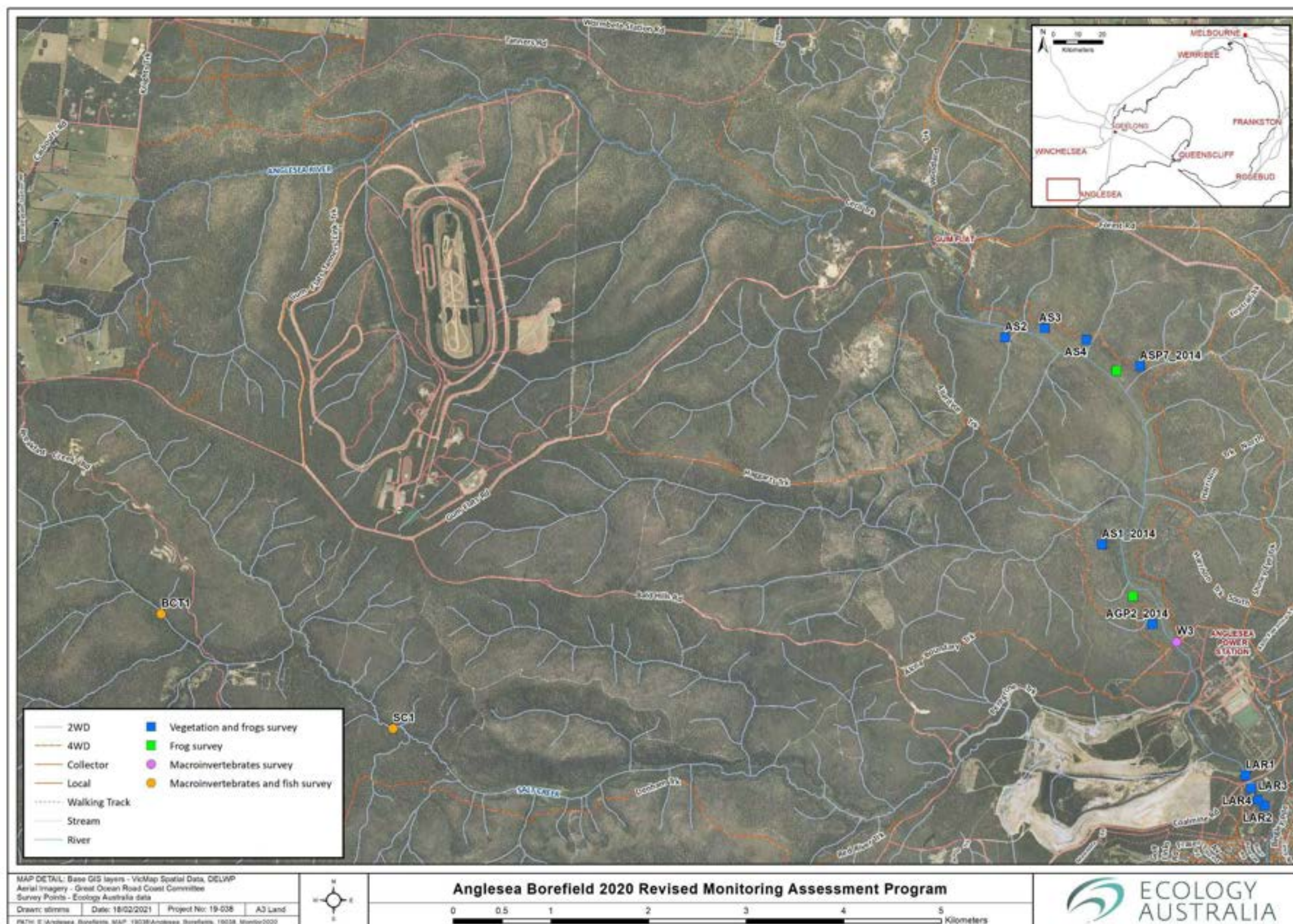


Figure 1 Anglesea Borefield ecological Monitoring and Assessment Program survey sites, 2020

2 Methods

The aquatic and terrestrial ecology monitoring methods that are provided here follow the revised MAP requirements and remain unchanged since the last round of monitoring conducted in 2017 (Ecology Australia 2017). They are repeated in this report for ease of reference.

2.1 Vegetation

Field work was carried out in the second week of November 2020. Vegetation monitoring was conducted at the following sites in the Anglesea Swamp: AS1_2014, AS2, AS3, AS4, ASP7_2014 and, AGP2_2014 and the following sites in the Anglesea Estuary: LAR1, LAR2, LAR3, and LAR4.

2.1.1 Floristic composition

At each of the sites, plant species and Ecological Vegetation Classes (EVCs) following the Department of Environment, Land, Water and Planning (DELWP) benchmarks (DELWP 2019a) were recorded in sequential 1 m² quadrats located along established 100 m transects. The start and end of all transects are marked by steel pickets. The quadrats are located every second meter along the left-hand side of the transect looking from start to end, with the first quadrat placed at 1–2 m, the second quadrat placed at 3–4 m and so on to 99–100 m.

There are 50 quadrats along each transect in the swamp, 15 quadrats along LAR2, LAR3 and LAR4 transects and 7 quadrats along LAR1 in the estuary.

Field staff walk on the right-hand side of the transect to avoid trampling vegetation within the quadrats.

Plant species were placed into respective plant Functional Groups (FGs) (see Table 1). The FGs and composition of EVCs were analysed to assess hydro-ecology (Section 2.1.2) and structure (Section 2.1.3).

2.1.2 Hydroecology

The FGs and EVCs were used to assess the degree of groundwater-dependent vegetation across the swamp and estuary and the sensitivity of sites to groundwater drawdown.

FGs (Table 1) is based on the hydro-ecology (known or likely water requirements) of plant species, modified from Cassanova (2011) and Doeg et.al. (2012) as detailed in Ecology Australia (2013b).

FG data is presented in two forms for each of the sites:

- Frequency and FG of the three most dominant species along the transect; and
- Frequency of each broad FG along the transect.

2.1.3 Structural attributes

Vegetation structure was documented through the recorded EVCs, dominant plant species and photo points. Photo points are located at 0 m, 25 m, 50 m, and 75 m along each transect in the swamp and the start of each transect in the estuary. Photos were taken looking toward the end of the transect.

2.1.4 Other attributes

Other transect attributes recorded were water depth (in the swamp only) and percentage cover of bare ground, rounded to the nearest 5%. Bare ground was estimated differently from previous surveys and

results should be interpreted considering this. In 2020 if there was standing water it was also recorded as bare ground for the quadrat.

Water depth is a snap shot in time (one day of the year) and will vary considerably over time depending on rainfall. Hydroperiod is a fundamental driver of wetland condition (e.g. Foti et al. 2012).

Bare ground provides space for plant recruitment. This can indicate potential change at a site, for example — are the extant FGs recruiting, or are conditions favouring the recruitment of drier or wetter groups?

In 2016, large amounts of ‘algal mat’ (consisting of filamentous algae) were observed in quadrats for the first time since the revised MAP monitoring commenced in 2014. The presence of an algal mat was noted again in 2020, with presence being recorded for each quadrat.

2.1.5 Wetland boundaries

Wetland boundaries in the Anglesea Swamp were confirmed as far as practicable by mapping the interface between Swamp Scrub and Aquatic Sedgeland using aerial imagery and ground-truthing. This mapping should detect significant boundary shifts in response to any longer-term hydrological change.

Table 1 Anglesea Borefield, ecological Monitoring and Assessment Program, Plant Functional Groups (modified from Cassanova 2011 and Doeg et.al. 2012)

Functional group code	Definition	Example species	Broad category
Tdr	<i>Terrestrial dry</i> . This species group does not require flooding and will persist in damper parts of the landscape because of localised high rainfall. Species in this group can invade or persist in riparian zones and the edges of wetlands, but are essentially terrestrial.	Messmate, Brown Stringybark, Prickly Moses, Silver Banksia	Dry
Tda	<i>Terrestrial damp</i> . These species germinate and establish on saturated or damp ground, but cannot tolerate flooding in the vegetative state. They require the soil profile to remain damp for at least several months.	Swamp Gum, Variable Sword-sedge, Manuka, Slender Bog-sedge	
ATI	<i>Amphibious fluctuation tolerator - low-growing</i> . This species group can germinate either on saturated soil or under water and grow submerged, as long as they are exposed to air by the time they start to flower and set seed. They require or tolerate shallow flooding for approximately 3 months.	Austral Brookline, Swamp Club-sedge, Spotted Knotweed	Amphibious
ATe	<i>Amphibious fluctuation tolerator-emergent</i> . This species group consists of emergent monocots and dicots that survive in saturated soil or shallow water but require most of their photosynthetic parts to remain above the water (emergent). They tolerate fluctuations in the depth of water, as well as water presence. They need water or soil moisture to be present for 8-12 months of the year.	Tall Sedge, Red Fruit Saw-sedge, Pouched Coral-fern, Scrambling Coral-fern	
ATw	<i>Amphibious fluctuation tolerator- woody</i> . This species group consists of woody perennial species that may hold their fruits (and seeds) in the canopy and require water to be present in the root zone all year round but will germinate in shallow water or on a drying substrate.	Woolly Tea-tree, Scented Paperbark	
ARp	<i>Amphibious fluctuation responder- plastic</i> . This species group occupies a similar zone to the ATI group, except that they have a morphological response to water level changes such as rapid shoot elongation or a change in leaf form. They can persist on damp and drying soil because of their morphological flexibility but can flower even if the site does not dry out. They occupy a slightly deeper/wet-for-longer site than the ATI group.	Creeping Cotula, Monkey Flower, River Buttercup	Aquatic
Se	<i>Perennial-emergent</i> . This category refers to monocotyledonous species that require permanent water in the root zone but remain emergent. They occur where water levels do not fluctuate or fluctuate with a relatively little drawdown in the dry part of the year.	Cumbungi, Sea Rush, Southern Water-ribbons	

2.2 Frogs

Zoologists undertook two repeat surveys for frogs at 12 sites, on 4 and 5 November and again on 25 and 26 November (before operation of the borefield):

- AS1_2014, AS2, AS3, AS4, AS5, AS6, ASP7_2014 and AGP2_2014 in the Anglesea Swamp; and
- LAR1, LAR2, LAR3 and LAR4 in the Anglesea Estuary (Figure 1).

Survey sites comprise the ten sites required by the MAP, as well as two additional sites (AS5 and AS6), which are surveyed if very low frog activity is observed in the Anglesea Swamp.

2.2.1 Habitat assessment and water quality

To supplement the habitat data collected as part of vegetation monitoring, the following variables were recorded about frog habitat:

- Wetland permanence (i.e. ephemeral, semi-permanent or permanent);
- Water quality parameters:
 - Temperature (° C);
 - pH;
 - Electrical Conductivity (EC);
 - Dissolved Oxygen (DO); and
 - Turbidity (NTU).
- A general habitat description, including levels of cover of fringing, emergent, submergent and floating vegetation where present.

Photos were also taken showing characteristic frog habitat at each survey site.

2.2.2 Frog surveys

Zoologists used both diurnal and nocturnal visual encounter surveys to detect frogs at the survey sites. Nocturnal surveys also included call playback and spotlighting. Weather conditions at the time of the survey were recorded using a Kestrel weather meter. In 2020, all frog sampling events were completed during suitable weather in Spring.

Visual encounter surveys

Visual and aural encounter surveys were undertaken at each site during the diurnal habitat assessment and the beginning of each nocturnal survey. Surveys comprised two zoologists listening for approximately five minutes for the distinctive calls of male frogs. The species heard, and an estimation of the number of frogs calling for each species was recorded. In addition, zoologists looked for frogs at each site, by traversing the sites and scanning vegetation and the water surface for the presence of frogs. Visual encounter during nocturnal surveys was aided by the use of head-torches and/or hand-held spotlights, to look for the distinctive eye-shine of frogs.

Nocturnal call playback

Call playback was used following the nocturnal aural survey, in an attempt to elicit calling behaviour by male frogs that were not calling independently onsite. This approach uses the broadcast of pre-recorded calls of each species through a speaker, followed by a period of quiet listening. Frog calls broadcast during call playback, based on previous records included:

- Southern Brown Tree Frog *Litoria ewingii*;
- Southern Bullfrog *Limnodynastes dumerilii*;
- Spotted Marsh Frog *Limnodynastes tasmaniensis*;
- Striped Marsh Frog *Limnodynastes peronii*;
- Common Spadefoot Toad *Neobatrachus sudellae*;
- Victorian Smooth Froglet *Geocrinia victoriana*; and
- Common Froglet *Crinia signifera*.

Call response data were used to estimate frog species richness and abundance within each site across the Anglesea Catchment and Estuary.

2.3 Aquatic ecology

2.3.1 Macroinvertebrate surveys

Macroinvertebrate surveys were undertaken at three sites on 5–6 November 2020. The relocated Site BCT1 was sampled, consistent with previous years (Ecology Australia, 2019) and will continue to be referred to as BCT1. Wetland 2 and Wetland 3 were again combined into a single site, as they act as a single waterbody due to connectivity between the two sites, and as there was insufficient water in either one to collect three samples.

As per the established methods (GHD 2016), triplicate edge samples were collected at each site where sufficient surface water was present, following the methods outlined in the Victorian Rapid Bioassessment (RBA) Methodology for Rivers and Streams (EPA 2003). A 250 µm mesh net with a 30 cm x 30 cm opening was used to collect each sample. Edge ('sweep') samples were collected from water bodies with little to no flow. The sampling objective was to subsample all types of habitats present, which can include overhanging vegetation, coarse woody debris, backwaters, bare edges, leaf packs and macrophytes. Each sample consisted of 10 m of habitat, which was not necessarily contiguous. The water and habitat were agitated to dislodge macroinvertebrates and suspend them within the water column.

Samples were live-sorted ('picked') following the standard RBA procedures and preserved in 70% ethanol. In summary, the procedures entail:

- Picking for 30 minutes from a white tray, aiming to collect 200 animals from as many different taxa as possible;
- If less than 200 animals are collected within 30 minutes, then picking continues for an additional 10 minutes;

- If 200 animals are collected within 40 minutes and no new taxa are detected, then picking ceases; otherwise picking continues for an additional 10 minutes. This continues until a maximum of 60 minutes of picking has been completed; and
- Avoidance of favouring large and abundant taxa over smaller, more cryptic taxa, by picking a maximum of approximately 30 of each taxa, except groups that typically require microscopic examination to identify to the taxonomic resolution of family (e.g. Amphipoda) or taxa which are to be identified to a lower taxonomic resolution than family (e.g. Chironomidae, and families of Odonata, Ephemeroptera, Plecoptera and Trichoptera).

At each site, RBA field sampling and habitat assessment sheets were completed, including in situ water quality measurements using a calibrated U-52 Horiba water quality meter.

Since the detection of Otway Bush Yabby in 2017, this species has been monitored concurrently with the effort that was being employed for fish and macroinvertebrates (Ecology Australia 2018–2020).

Macroinvertebrate identification

Macroinvertebrates were identified and enumerated with a stereo microscope using keys outlined in MDFRC (2013), which provides an update on those outlined in Hawking (2000). The majority of taxa were identified to family level with the following exceptions as per the RBA protocols (EPA 2003):

- Chironomidae are identified to sub-family;
- Oligochaeta and Acarina are not identified below these taxonomic levels;
- Adult and larval beetles are listed separately;
- Taxa excluded from the recommended indices were discarded;
- Specimens of the orders Ephemeroptera, Plecoptera, Trichoptera and Odonata were identified to genus level, as per GHD (2015–2017) and Ecology Australia (2018–2020).

2.3.2 Macroinvertebrate data analyses

Macroinvertebrate data were analysed both as individual samples and on a site basis using the combined data from three samples. Where available, the results were compared against indices objectives outlined in State Environment Protection Policy – Waters (SEPP(W); Victorian Government Gazette 2018) about surface water in the Central Foothills and Coastal Plains geographic region. Where there is no relevant index available in the SEPP (W) the results were compared against the indices used in previous reports.

The following indices were used to analyse macroinvertebrate data:

- Number of taxa — total number of taxa based on taxonomic resolution levels described above;
- SIGNAL2 score — average SIGNAL score for taxa collected in each sample, based on methods of Chessman (2003). Table 2 provides the corresponding water quality categories;
- Number of EPT taxa — number of taxa from the orders Ephemeroptera, Plecoptera and Trichoptera (EPT). These taxa are typically considered more sensitive to pollution and disturbance and hence the index is an indicator of ecosystem health; and

- Number of EPTO taxa — number of taxa from the orders of Ephemeroptera, Plecoptera, Trichoptera and Odonata (EPTO). This modified version of the EPT index is used for waterways in 'Mediterranean climate' regions, and aid in interpreting the health of lentic (still water) systems, where the numbers of Plecoptera are diminished while Odonata, which are also relatively sensitive to pollutants and disturbance, are more abundant and diverse (Pinto et al. 2004).

Table 2 SIGNAL score classifications (Chessman 1995)

SIGNAL score	Water quality
>7	Excellent
6-7	Clean water
5-6	Mild pollution
4-5	Moderate pollution
<4	Severe pollution

2.3.3 Fish surveys

Surveys targeting Southern Pygmy Perch *Nannoperca australis* and Otway Bush Yabby *Geocharax tasmanicus* were undertaken at two sites; SC1 and BCT1 on 5–6 November 2020. As with the macroinvertebrate surveys, site BCT1 was relocated downstream due to insufficient surface water.

Ten bait traps (stretched mesh size of 2 mm and funnel entrances of 4 cm diameter) with 10 cm long yellow glow sticks were set in the afternoon and retrieved the following morning at both sites. This is consistent with the monitoring approach used in recent years (Ecology Australia 2018–2020), where the number of traps per site was increased to increase the number of Southern Pygmy Perch.

The first 30 Southern Pygmy Perch captured at each site were required to be measured (total length) to the nearest millimetre and weighed to the nearest 0.1 gram. All remaining Southern Pygmy Perch was recorded as a total number of individuals per site.

All captures of Otway Bush Yabby were recorded per sampling method and per replicate (with individuals captured both within the bait traps and within sweep samples). All Otway Bush Yabbies captured using the latter method were picked out of the sample and returned to the point of capture before macroinvertebrate samples were live-picked as described above (see: section 2.3.1).

Instream habitat assessment was undertaken at all sites surveyed. The habitat assessment included notes on existing sources of disturbance, notes and estimates of biological and physical attributes (e.g. wetted instream cover, riparian shading, aquatic vegetation, substrate composition, flow and depth) and in situ water quality measurement. An outline of some of these habitat descriptors is provided below:

- The percentage cover of various forms of instream habitat (based on the proportion of the wetted area that they covered at the time of assessment).
- The shading estimate as per the EPA Rapid Bioassessment method (EPA 2003). This is an estimate based on a plan view as it would appear with the sun directly overhead (i.e. midday).

- The flow status estimate is as per the USEPA field sheets that are incorporated into the latest iteration of the Victorian EPA Rapid Bioassessment field sheets (Version: September 2012). This is an estimate based on the proportion of the channel filled and/or substrate exposed.
- The disturbance rating estimate is based on the identification of several disturbance sources including levels of bank erosion, riparian vegetation clearance, parallel or adjacent roads, bridges/culverts/fords, rubbish, drain input, water extraction points, stock access, sedimentation, invasive exotic vegetation, barriers to fish passage, channelization and hydrological alterations; together with a severity rating (i.e. high, medium, low) applied to the disturbance sources that were identified at a given site.

Water quality measurements (dissolved oxygen (mg/L), pH, temperature (degrees Celsius), conductivity (mS/cm) and turbidity (NTU)) were made with a calibrated Horiba U-52 water quality meter.

2.4 Conservation status

Threatened species of State and/or National conservation significance were determined by reference to the Victorian Government Advisory Lists (DSE 2009, 2013, DEPI 2014) in addition to listings under the Victorian *Flora and Fauna Guarantee Act 1988* (FFG Act) and the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

2.5 Nomenclature and taxonomy

All scientific names, common names and systematic orders of flora and fauna species follow the Victorian Biodiversity Atlas (DELWP 2019b), with common names referring to fauna within the text of the report.

Where an asterisk (*) precedes a plant name it is used to signify non-indigenous taxa, those species which have been introduced to Victoria or Australia. A hash (#) is used to denote Victorian plant species that are not indigenous to the region or local area.

3 Results

Vegetation and frog monitoring were undertaken at the same sites (with two additional sites for frogs). Findings for each site are presented below followed by site summaries in Section 4.2.3.

The aquatic ecology monitoring was carried out at sites in different locations to the terrestrial monitoring sites and as such the site summaries are presented separately in Sections 4.3.

3.1 Vegetation

Site summaries displaying the results of the vegetation monitoring area provided in Figures 2, 4, 6, 8, 10, 12, 16, 18, 20 and 22.

3.1.1 Floristic composition

A total of 27 indigenous plant species were recorded across all sites in the Anglesea swamp (Appendix 1), while in the Anglesea estuary a total of 19 indigenous plant species, eight exotic plant species and two native Victorian species not indigenous to the location were recorded (Appendix 2).

Native species richness at any one site ranged from 8–15 in the swamp and 9–14 in the estuary (Table 3).

Table 3 Anglesea Borefield ecological Monitoring and Assessment Program, number of native plant species recorded across monitoring sites and Functional Groups, November 2020.

Transect/Site	Total number of native plant species	Number of plant species in a dry Functional Group (Tdr, Tda)	Number of plant species in an Amphibious Functional Group (Ate, ATw, ARp)	Number of plant species in an Aquatic Functional Group (Se)
Anglesea Swamp				
AS2	13	7	4	2
AS3	10	2	7	1
AS4	15	3	9	3
ASP7_2014	14	3	9	2
AS1_2014	12	5	4	3
AGP2_2014	8	1	5	2
Anglesea Estuary				
LAR1	9	3	4	2
LAR2	12	6	4	2
LAR3	14	9	4	1
LAR4	9	4	3	2

No weeds were recorded in 2020 in the swamp and there was little sign of recent disturbance.

3.1.2 Hydro-ecology

In the Anglesea Swamp, five FGs were represented (Tda, Tdr, Se, Ate and ATw) by at least one species recorded for each functional group (Table 3). No plants from the ATI or ARp FG's were recorded. Plants from five FG's were also recorded in the Anglesea estuary (Tda, Tdr, Se, ATe and ARp) and no plants from the ATI or ATw FGs were recorded (Table 3).

The percentage frequency of species at each site (occurring across 50 quadrats) was recorded during each survey period between 2014 and 2020 at Anglesea Swamp. Table 4 shows a summary of the plants and their associated functional (hydro-ecological) groups that appeared to show trends of change over time in the percentage frequency.

Table 4 Plant species, and the associated functional group, that showed trends of change for each site over time at Anglesea Swamp.

Sites	Functional Group	Scientific Name	Quadrats Occupied (% frequency)					
			2014	2015	2016	2017	2019	2020
AGP2_2014	Se	<i>Cycnogeton procerum</i> sp. aff.	82	80	96	92	90	96
	ATe	<i>Juncus procerus</i>	70	74	74	72	62	36
AS1_2014	Se	<i>Eleocharis sphacelata</i>	20	10	4	4	4	8
	Se	<i>Machaerina arthropphylla</i>	58	52	52	54	0	4
AS2	Se	<i>Cycnogeton procerum</i> sp. aff.		12	44	44	26	26
	Se	<i>Machaerina tetragona</i>	46	52	46	50	26	34
ASP7_2014	Se	<i>Cycnogeton procerum</i> sp. aff.	18	16	88	90	76	80
	Se	<i>Machaerina arthropphylla</i>	80	78	76	78	72	58

There were five wetland plant species across two main functional groups (Table 4) that showed trends of change over time, for the percentage frequency, of the number of quadrats occupied between 2014 and 2020 surveys.

Site AGP2_2014 has shown a 50% decline in the frequency of occurrence of Tall Rush *Juncus procerus* in 2020 with 36% from 72% in 2017. The functional group of this plant is described as an Amphibious Fluctuation Tolerator- emergent (ATe). Table 1 describes this functional group as including plants that require 8-12 months per year of flooding as long as a proportion of the plant is emergent from the water throughout the year.

Site AS1_2014 showed downward trends in two species from the Perennial Emergent (Se) functional group. This functional group is described in Table 1 as monocotyledonous species requiring permanent water within the root zones of the plant, without water drawing down totally throughout the dry part of the year. Tall Spike-rush *Eleocharis sphacelata* showed a large decrease of percentage frequency between 2014 (20%) and 2016 (4%) with the 2020 result being 8% frequency. The percentage frequency of Fine Twig-sedge *Machaerina arthropphylla* was relatively stable between 2014 and 2017 monitoring years, ranging from 52-58% frequency. After 2017 this species dropped to the point that it was not recorded in 2019 and only 4% frequency in 2020.

Site AS2 showed trends of change over time of the percentage frequency in two wetland species from the Perennial Emergent (Se) functional group. Water Ribbons *Cynnogeton procerum* sp. aff. showed an initial increase in percentage frequency from 0% in 2014 to 44% in 2017. In 2019 and 2020 there was a decrease to 26% frequency. Square Twig-sedge *Machaerina tetragona* was relatively stable between 2014 and 2017 monitoring years, ranging from 46-50% frequency. After 2017 this species dropped to 26% frequency in 2019 and 24% in 2020.

Site AS2 showed trends of change over time of the percentage frequency in two wetland species from the Perennial Emergent (Se) functional group. Water Ribbons showed an initial increase in percentage frequency from 0% in 2014 to 44% in 2017. In 2019 and 2020 there was a decrease to 26% frequency. The percentage frequency of Fine Twig-sedge was relatively stable between 2014 and 2017 monitoring years, ranging from 76-80% frequency. After 2017 this species has trended down to 72% frequency in 2019 and only 58% frequency in 2020.

The vegetation in the estuary remains relatively healthy. Non-indigenous plants were recorded in all estuary sites except in LAR4. In sites LAR1, LAR2 and LAR3, indigenous plants were recorded in comparatively greater numbers in each transect (Appendix 2), and indigenous plants were recorded more frequently than weeds in all transects (Figures 16, 18, 20 and 22).

3.1.3 Structural attributes

Three EVCs recorded in the swamp in 2020 were: Swamp Scrub, representing an open to closed shrubland to 4 m high, Aquatic Sedgeland, characterised by a variably dense cover of sedges to 1.3 m, and Heathy Woodland generally bordering the swamp which has a eucalypt canopy over a shrubby understory. The wetland vegetation was dominated by plants in the Amphibious and Aquatic FGs (Figures 2, 4, 6, 8, 10 and 12).

In the estuary, two EVCs were recorded: Swampy Riparian Woodland which consisted of a low open eucalypt canopy to 8 m tall with an understory of scattered woody shrubs and small herbs, and Estuarine Wetland consisting of a dense cover of reeds and rushes to 1 m, with scattered tussock grasses and small herbs. The wetland vegetation was dominated by plants in the Amphibious and Aquatic FGs (Figures 16, 18, 20 and 22).

3.1.4 Other attributes

Water was present at all six sites in the swamp and the average depth ranged from 2.5 – 16.5 cm (Figures 2, 4, 6, 8, 10 and 12).

Bare ground was recorded in all sites at the swamp in 2020 and ranged from an average of 3% in transect AS3 to 68% in transect AS1_2014 (Figures 2, 4, 6, 8, 10 and 12). Bare ground was only recorded at transect LAR2 in the estuary at an average of 1% (Figures 16, 18, 20 and 22).

Algal mat was recorded at three sites in the swamp and the number of quadrats it was recorded in ranged from 5 (AS4) to 38 (AS1_2014) (Figures 2, 4, 6, 8, 10 and 12). Algal mat was recorded in two quadrats at one site in the estuary (LAR1).

3.1.5 Wetland boundaries

No changes were observed in the wetland boundaries between the Aquatic Sedgeland and the Swamp Scrub, or between these two EVCs and the adjoining Heathy Woodland (Figures 24–25).

3.2 Frogs

3.2.1 Survey conditions

The first round of frog surveys was conducted on 4–5 November 2020, seven of the eight Anglesea Swamp monitoring sites had open standing water, with AS5 being mostly moist with shallow (ca. 0.1 m) pools of water located near the centre of the survey site. By the second survey, AS5 had become too shallow to provide reliable water quality measurements. Overall, water levels were similar to those observed in previous years. However, due to a strong winds event, it was not possible to complete the first frog survey at site AS2.

The second frog survey was conducted on 25–26 November 2020. Conditions during both frog surveys were suitable for detecting frogs, with low wind, moderate temperatures, and relatively high humidity; no rain fall occurred during or immediately before either survey (Table 5).

Table 5 Weather conditions during frog surveys, Anglesea revised ecological Monitoring and Assessment Program, 2020.

Variable	Survey 1	Survey 2
Temperature (°C)	13.75	13.15
Humidity (%)	78.1	81.61
Cloud cover (0–8)	2.90	1.25
Moon light (0–4)	0	2.5
Wind speed (0–3)	0	0
Rainfall during survey (0–3)	0	0
Rain in past 24 hours (None–heavy)	None	None

3.2.2 Frog species richness and abundance

Anglesea Swamp

There were no frogs were observed during either survey at any of the long-term survey points located within the Anglesea Swamp. During the second survey, Southern Brown Tree Frogs were heard calling from near two sites more than 100 m away, while Southern Bullfrogs were heard near one site (Table 6). Both species were heard calling near AS3, on Harrison Track North. A maximum of five individuals of each species was heard calling near the survey sites. In addition, two Common Froglet were detected calling during the vegetation assessment at AS2.

Anglesea Estuary

Frogs were heard calling in the vicinity (<100 m) of the long-term survey points during each of the surveys at the Anglesea Estuary. One Southern Bullfrog was observed active beside the walking track between LAR4 and LAR2 (Plate 3), with another two individuals observed floating and calling within the creek near LAR2 during the first survey. Typically, Southern Brown treefrogs and Southern bullfrog were

heard calling from within 100 m of each of the survey sites during both surveys (Table 6), often in large numbers of both species of frogs (between 10 and 20 individuals) around the estuary.

Table 6 Anglesea Borefield revised ecological Monitoring and Assessment Program, frog species detected during nocturnal surveys and estimated abundances, 2020. The number of frogs heard calling at least 100 m from the survey sites are listed in parentheses.

Site	Southern Brown Tree Frog		Southern Bullfrog		Species Richness
	1	2	1	2	
Anglesea Swamp					
AS2	0	0	0	0 (1-5)	0
AS3	0	0 (1-5)	0	0 (1-5)	0
AS4	0 (1-5)	0	0	0	0
AS5	0	0	0	0	0
ASP7_2014	0	0	0	0	0
AS1_2014	0	0	0	0	0
AS6	0	0 (1-5)	0	0	0
AGP2_2014	0	0	0	0	0
Anglesea Estuary					
LAR1	0 (1–5)	0 (1–5)	0 (1-5)	0 (1-5)	0
LAR2	0 (1–5)	0 (1–5)	2 (6–10)	0 (6–10)	1
LAR3	0 (5–10)	0 (1–5)	0 (6–10)	0 (1–5)	1
LAR4	0 (6–10)	0 (6–10)	1 (6–10)	0 (1–5)	0



Plate 1 Southern Bullfrog *Limnodonastes dumerilii* observed beside walkway at the Anglesea Estuary, near LAR4. Photo: Ruth Marr.

3.2.3 Habitat assessment and water quality

Anglesea Swamp

The Anglesea Swamp monitoring sites mostly support dense shrub cover of Scented Paperbark *Melaleuca squarrosa* and Prickly Teatree *Leptospermum continentale*, which open up into clearings of emergent aquatic vegetation, largely sedges such as Zig-zag Bog-sedge *Schoenus brevifolius*, Square Twig-sedge *Machaerina tetragona* and Fine Twig-sedge *M. arthropophylla*. Swards of dead and live sedges occasionally form thick mats across the site. Fringing vegetation sometimes includes shorter Pink Swamp-heath *Sprengelia incarnata* or Pouched Coral-fern *Gleichenia dicarpa*. Where monitoring sites support standing water, Common Water-ribbons *Cyanogeton procerum* sp. aff. and filamentous algae may be present as submergent and floating vegetation. Some sites also include small patches of bare ground and low cover of woody debris, especially at the interface between emergent and fringing vegetation.

All monitoring sites are considered intermittent except for AS3 (semi-permanent) and AS4 (semi-permanent to permanent). During the 2020 surveys, all sites had sufficient standing water to allow for all water quality parameters to be measured during the first survey. This had declined by the second survey such that three sites (AS5, AS6 and ASP7) had insufficient standing water to allow reliable water quality measurement. Most sites were acidic (pH of 3.41–8.31) and electric conductivity was low, ranging from 0.02 to 3.93 $\mu\text{S}/\text{cm}$. Water temperatures were relatively high, with all but three measurements above 15 °C (range: 13.1–21.8 °C). Turbidity was more variable across sites, being generally low (range: 0 – 66 NTU) with most values being under 15 NTU. Similarly, dissolved oxygen levels were variable (range: 1.55–9.17 mg/L).

Anglesea Estuary

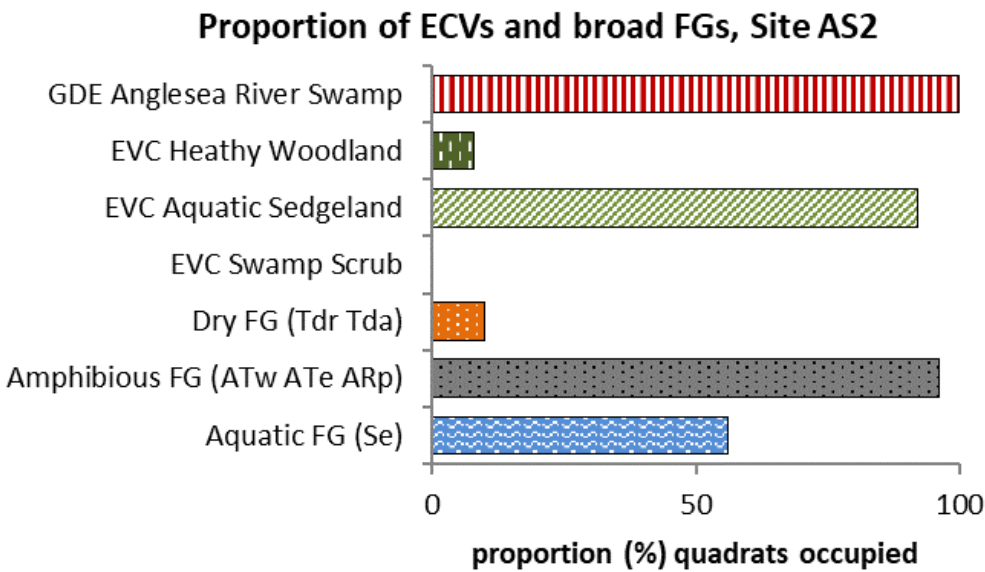
The Anglesea Estuary is relatively deep, with slow-moving water. Apart from filamentous algae, the cover of aquatic vegetation was generally low, particularly the cover of floating and submergent vegetation. Common Reed *Phragmites australis* provides sparse emergent vegetation at most sites. Fringing vegetation occurs at higher levels of cover, dominated by grasses, sedges, rushes and herbs including Coast Tussock-grass, *Poa poiformis* var. *poiformis*, Common Blown-grass *Lachnagrostis filiformis*, Sea Rush *Juncus kraussii* ssp. *australiensis* and Shiny Swamp-mat *Goodenia radicans*. LAR1 also supports Narrow-leaf Cumbungi *Typha domingensis* and Southern Water-ribbons. Scattered shrubs of Hop Goodenia *Goodenia ovata* and Manuka *Leptospermum scoparium* and stands of Swamp Gum *Eucalyptus ovata* var. *ovata* were recorded near the water's edge.

All estuary monitoring sites are considered permanent, with stream widths ranging from 2–3 m to approximately 9 m wide, and up to 2 – 3 m deep. As such water quality could be measured at all sites, and values were generally consistent between sites within surveys, compared to measurements taken in the Anglesea Swamp. All sites had very low pH (3.32–3.94), and water temperature was generally over 20 °C, apart from a cooler reading obtained at LAR1 in the second survey (18.4 °C). Electrical conductivity readings were relatively low, particularly in the second survey, with slightly lower recordings obtained at LAR1, further upstream. Conductivity remained constant with a mean of 7.82 µs/cm in the first survey, to 7.85 µs/cm in the second survey. Turbidity was low (0–5 NTU) and dissolved oxygen concentrations varied from 2.56 to 22.2 mg/L.

3.2.4 Vegetation and frog site summaries

The following site summaries include:

- transect photos at 25 m intervals;
- the proportion of each EVC and each FG recorded at each site;
- the top three dominant plant species and their FG;
- other attributes including average bare ground cover, water depth and algal mat;
- a habitat description;
- frog species occurrence and abundance;
- water quality data; and
- relevant comments.



Key:
GDE: Groundwater Dependent Ecosystem
EVC: Ecological Vegetation Class
FG: Functional Group

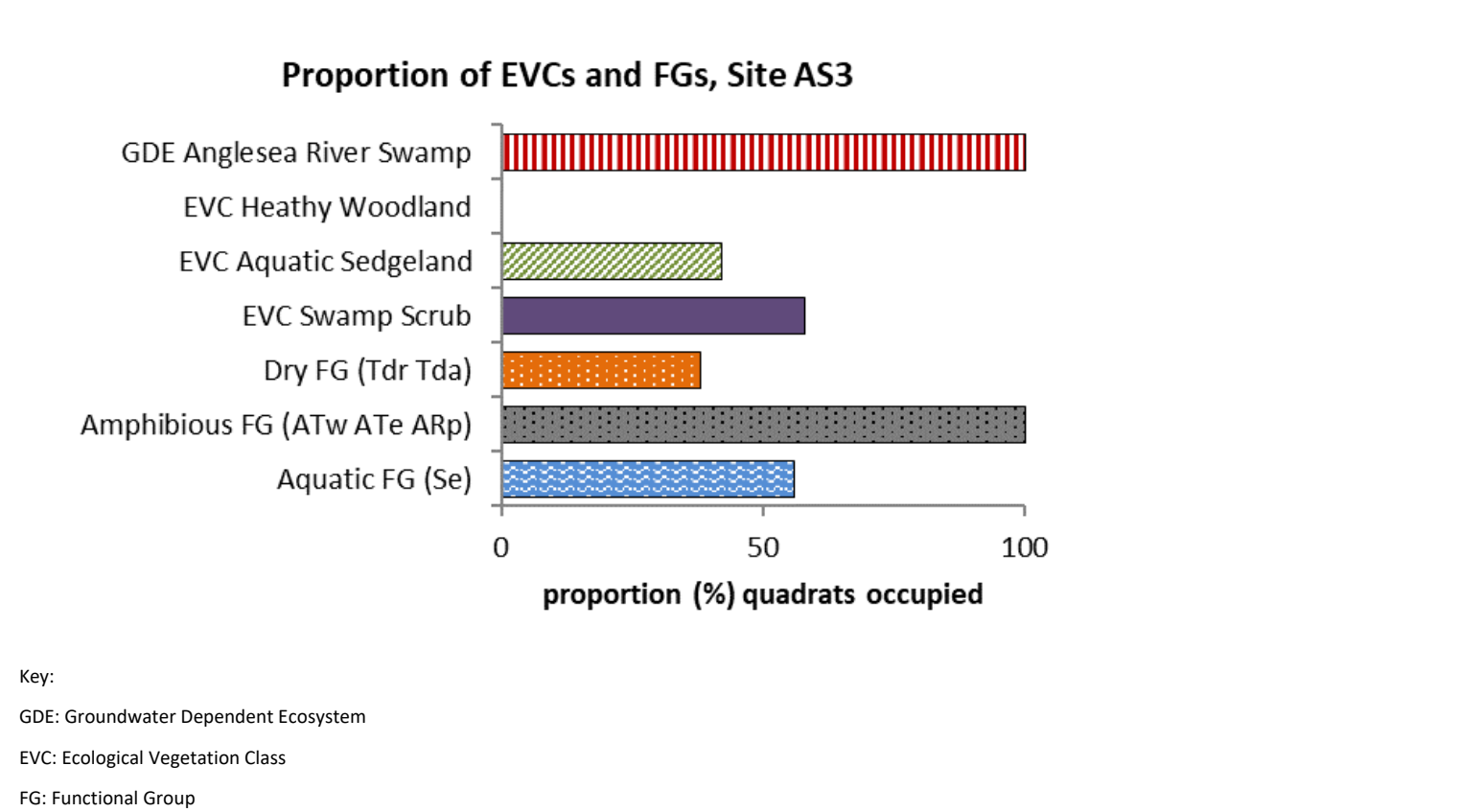
Dominant Plant Species		Broad FG	Quadrats occupied (% frequency)
<i>Schoenus brevifolius</i>	Zig-zag Bog-sedge	Amphibious	88
<i>Machaerina tetragona</i>	Square Twig-sedge	Aquatic	34
<i>Cycnogeton procerum sp. aff.</i>	Common Water-ribbons	Aquatic	26

Other attributes		
Average % bare ground cover	20	(bare ground recorded in 34 quadrats)
Average water depth along transect (cm)	9	Water recorded in 35 quadrats
Algal mat (quadrats occupied)	0	

Figure 2 Anglesea Borefield Monitoring and Assessment Program, Anglesea Swamp, Site AS2, vegetation summary data, 2020.

AS2: General habitat description					
Ecological Vegetation Class (EVC)			Aquatic Sedgeland		
Wetland permanence			Ephemeral		
Swamp dominated by emergent dead and live sedges, with patches of clear open water at varying depth to c. 20 cm. Open water contains 5% floating, 5-10% submergent vegetation and 70-100% emergent and floating debris and vegetation. The swamp is fringed with 70–100% shrub vegetation with small amounts of bare wet soil. Macropod and predator scats observed in swamp.					
AS2: Frog abundance and richness					
Southern Brown Tree Frog		Common Froglet		Southern Bullfrog	Species Richness
0		0		0	0
AS2: Water quality parameters					
Survey 1					
pH	4.12	Turbidity	42 NTU	Water temperature	15.5 °C
EC	1.28 µs/cm	Salinity	0.05%	Dissolved Oxygen	9.08 mg/L
Survey 2					
pH	6.61	Turbidity	104 NTU	Water temperature	19.1°C
EC	1.75 µs/cm	Salinity	0.08%	Dissolved Oxygen	4.32 mg/L
Comments					
Pools of up to 20 cm depth were present during the first survey. Site was not surveyed during the first frog survey event. Two Common froglets calling during vegetation assessment in the week following first frog survey. Southern bullfrog where detected calling in the distance on the second frog survey.					

Figure 3 Anglesea Borefield terrestrial revised ecological Monitoring and Assessment Program, Anglesea Swamp site AS2, 2020 frog summary data.



Dominant Plant Species		Broad FG	Quadrats occupied (% frequency)
<i>Schoenus brevifolius</i>	Zig-zag Bog-sedge	Amphibious	80
<i>Melaleuca squarrosa</i>	Scented Paperbark	Amphibious	70
<i>Sprengalia incarnata</i>	Pink Swamp-heath	Amphibious	68

Other attributes		
Average % bare ground cover	5	(bare ground recorded in 14 quadrats)
Average water depth along transect (cm)	2.5	Water recorded in 31 quadrats
Algal mat (quadrats occupied)	0	

Figure 4 Anglesea Borefield Monitoring and Assessment Program, Anglesea Swamp, Site AS3, vegetation summary data, 2020.

AS3: General habitat description					
Ecological Vegetation Class (EVC)			Swamp Scrub		
Wetland permanence			Semi-permanent		
Site consists of a small (c. 0.25 ha) clearing in shrub vegetation (Swamp Paperbark, Prickly Tea-tree and Pink Swamp-heath) with 70–100% cover of emergent dead and live sedges and small amounts of Pouched Coral-fern. Less than 5% cover of fallen branches was observed under fringing vegetation. Pools of standing water 15 cm depth in the first survey had declined to 5–10 cm deep by the second survey. There was shallow water < 5 cm deep present in the swamp in the second survey, but no pools. Macropod tracks present around the site.					
AS3: Frog abundance and richness					
Southern Brown Tree Frog		Common Froglet		Southern Bullfrog	
1-5		0		1-5	
Survey 1					
pH	3.86	Turbidity	15 NTU	Water temperature	13.1 °C
EC	1.38 µs/cm	Salinity	0.06%	Dissolved Oxygen	7.83 mg/L
Survey 2					
pH	4.66	Turbidity	66 NTU	Water temperature	15.0 °C
EC	1.36 µs/cm	Salinity	0.06%	Dissolved Oxygen	NA
Comments					
Southern Brown Tree Frogs (1-5 individuals) and Southern Bullfrogs (1-5 individuals) could be heard calling more than 100 m from observers. A male Koala was calling from nearby.					

Figure 5 Anglesea Borefield terrestrial revised ecological Monitoring and Assessment Program, Anglesea Swamp site AS3, 2020 frog summary data.



0—25m



25—50m

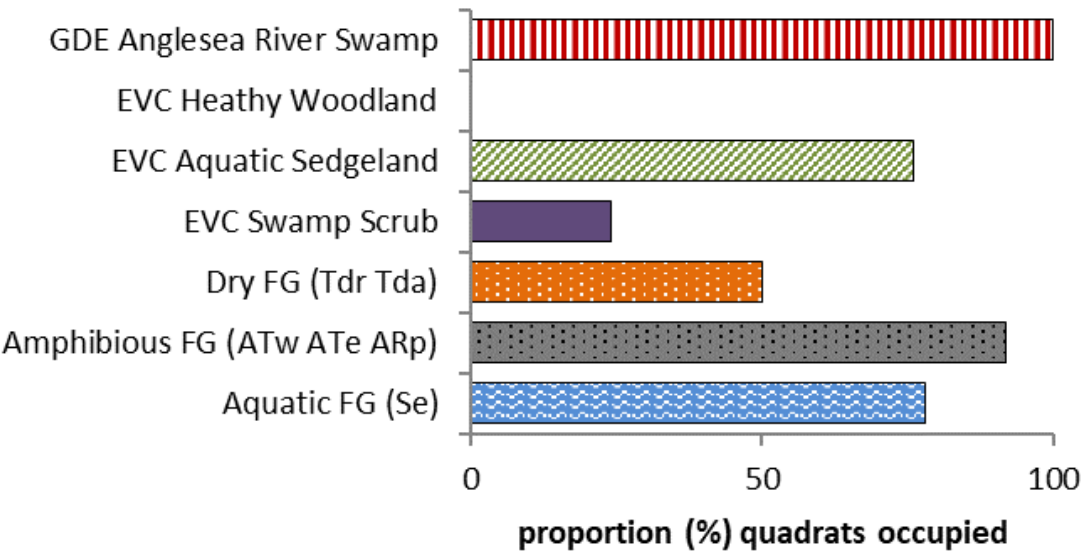


50—75m



75—100m

Proportion of EVCs and FGs, Site AS4



Key:
GDE: Groundwater Dependent Ecosystem
EVC: Ecological Vegetation Class
FG: Functional Group

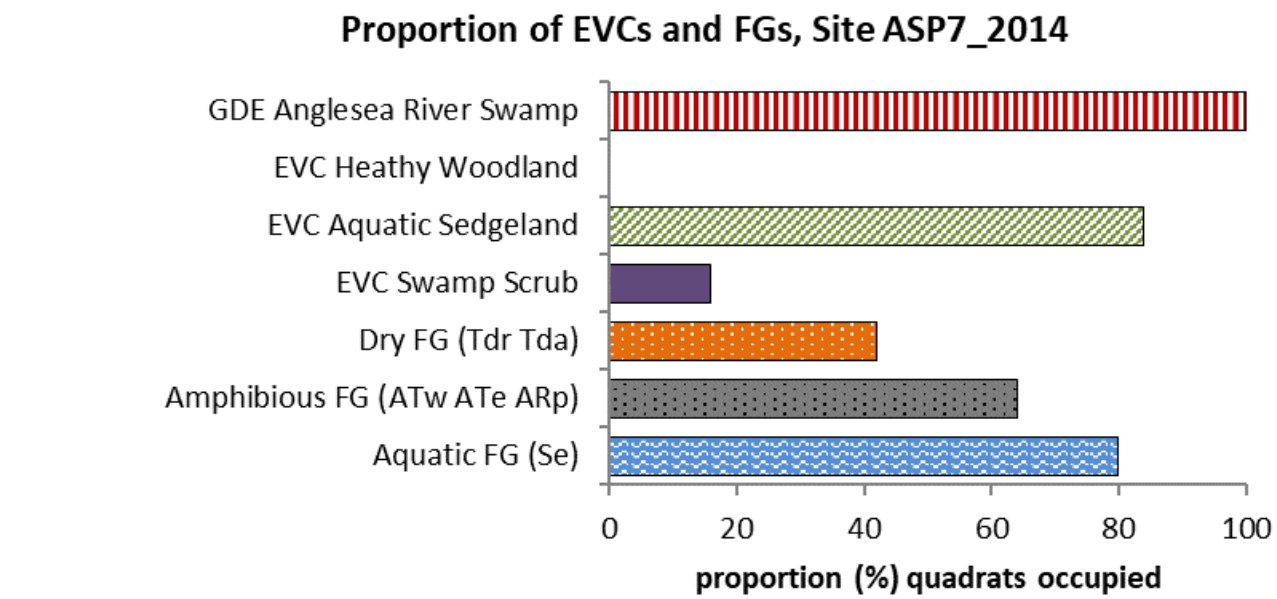
Dominant Plant Species	Broad FG	Quadrats occupied (% frequency)
Melaleuca squarrosa	Scented Paperbark	Amphibious 90
Cycnogeton procerum sp. aff.	Common Water-ribbons	Aquatic 76
Machaerina arthropylla	Fine Twig-sedge	Aquatic 68

Other attributes		
Average % bare ground cover	35	(bare ground recorded in 40 quadrats)
Average water depth along transect (cm)	6	Water recorded in 39 quadrats
Algal mat (quadrats occupied)	5	

Figure 6 Anglesea Borefield Monitoring and Assessment Program, Anglesea Swamp, Site AS4, vegetation summary data, 2020.

AS4: General habitat description					
Ecological Vegetation Class (EVC)			Aquatic Sedgeland		
Wetland permanence			Semi-permanent		
Survey site located on the perimeter of the swamp in fringing vegetation. Thick ground cover of Pouched Coral-fern to c. 1 m, with emergent (20-50%) Pink Swamp-heath and Scented Paperbark. Submergent vegetation (10-20%), with less than 5-10% cover of fallen branches, and small (5–10%) amounts of bare ground. Macropod tracks and scats observed at site.					
Southern Brown Tree Frog		Common Froglet		Southern Bullfrog	Species Richness
0		0		0	0
AS4: Water quality parameters					
Survey 1					
pH	3.60	Turbidity	8 NTU	Water temperature	15.3 °C
EC	2.20 µs/cm	Salinity	0.10%	Dissolved Oxygen	6.93 mg/L
Survey 2					
pH	4.82	Turbidity	9 NTU	Water temperature	13.8 °C
EC	2.41 µs/cm	Salinity	0.12%	Dissolved Oxygen	NA
Comments					
Water depth was adequate for water quality measurements, with the exception of dissolved oxygen. Southern Brown tree-frogs were detected calling in the direction of AS3. Two Southern Boobook owls were calling nearby < 200 m.					

Figure 7 Anglesea Borefield terrestrial revised ecological Monitoring and Assessment Program, Anglesea Swamp site AS4, 2020 frog summary data.



Key:
GDE: Groundwater Dependent Ecosystem
EVC: Ecological Vegetation Class
FG: Functional Group

Figure 8 Anglesea Borefield Monitoring and Assessment Program, Anglesea Swamp, Site ASP7_2014, vegetation summary data, 2020.

Dominant Plant Species	Broad FG	Quadrats occupied (% frequency)
<i>Cynnogeton procerum</i> sp. aff.	Common Water-ribbons	Aquatic 80
<i>Machaerina arthropphylla</i>	Fine Twig-sedge	Aquatic 58
<i>Schoenus brevifolius</i>	Zig-zag Bog-sedge	Amphibious 58

Other attributes		
Average % bare ground cover	35	(bare ground recorded in 47 quadrats)
Average water depth along transect (cm)	6.5	Water recorded in 46 quadrats
Algal mat (quadrats occupied)	0	

ASP7_2014: General habitat description					
Ecological Vegetation Class (EVC)			Aquatic Sedgeland		
Wetland permanence			Ephemeral		
Site consists of a large (c. 3 ha) clearing within the swamp, comprising c. 70% emergent sedges, fringed with c. 70-90% cover of mostly Scented Paperbark. During the first survey the swamp had an average depth of 0.2 m. The reduced depth observed during the second survey revealed a substrate of dead and decomposing vegetation. Vehicles tracks present at the southern edge of the site first observed in 2019 remain clearly visible as numerous wheel ruts.					
ASP7_2014: Frog abundance and richness					
Southern Brown Tree Frog		Common Froglet		Southern Bullfrog	
0		0		0	
Survey 1					
pH	3.41	Turbidity	1 NTU	Water temperature	17.8 °C
EC	2.56 µs/cm	Salinity	0.12%	Dissolved Oxygen	4.26 mg/L
Survey 2					
pH	NA	Turbidity	NA	Water temperature	NA
EC	NA	Salinity	NA	Dissolved Oxygen	NA
Comments					
Pools of up to 20 cm depth were present during the first survey, had become too shallow (<0.05 m) for water quality measurements during the second survey. There were no frogs detected during either survey.					

Figure 9 Anglesea Borefield terrestrial revised ecological Monitoring and Assessment Program, Anglesea Swamp site ASP7_2014, 2019 frog summary data.



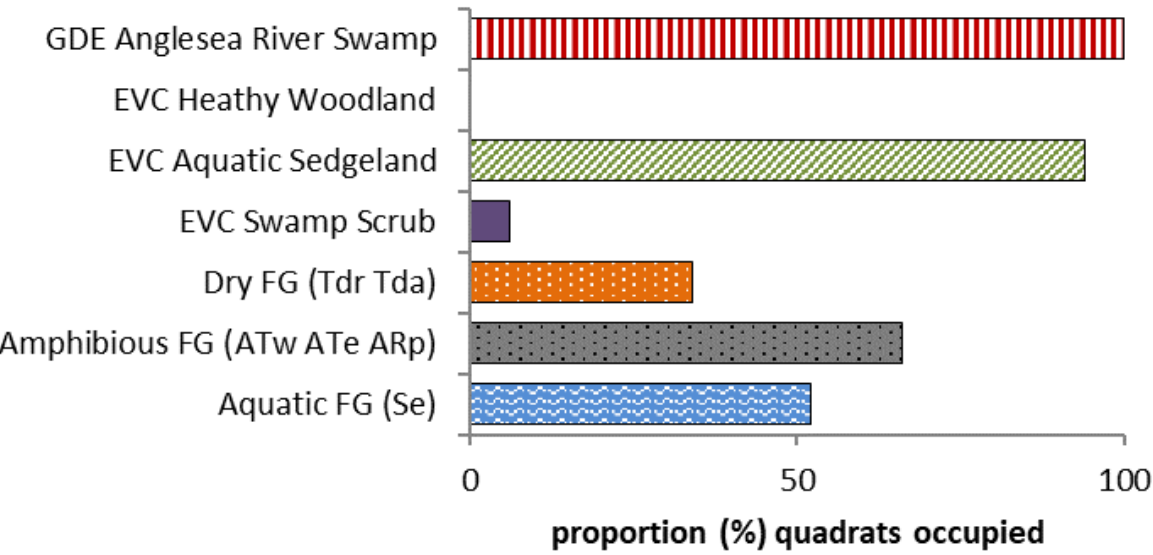
0—25m

25—50m

50—75m

75—100m

Proportion of EVCs and FGs, Site AS1_2014



Key:
GDE: Groundwater Dependent Ecosystem
EVC: Ecological Vegetation Class
FG: Functional Group

Dominant Plant Species	Broad FG	Quadrats occupied (% frequency)
<i>Schoenus brevifolius</i>	Zig-zag Bog-sedge	Amphibious 62
<i>Cynogeton procerum sp. aff.</i>	Common Water-ribbons	Aquatic 50
<i>Melaleuca squarrosa</i>	Scented Paperbark	Amphibious 32

Other attributes		
Average % bare ground cover	70	(bare ground recorded in 43 quadrats)
Average water depth along transect (cm)	9	Water recorded in 42 quadrats
Algal mat (quadrats occupied)	38	

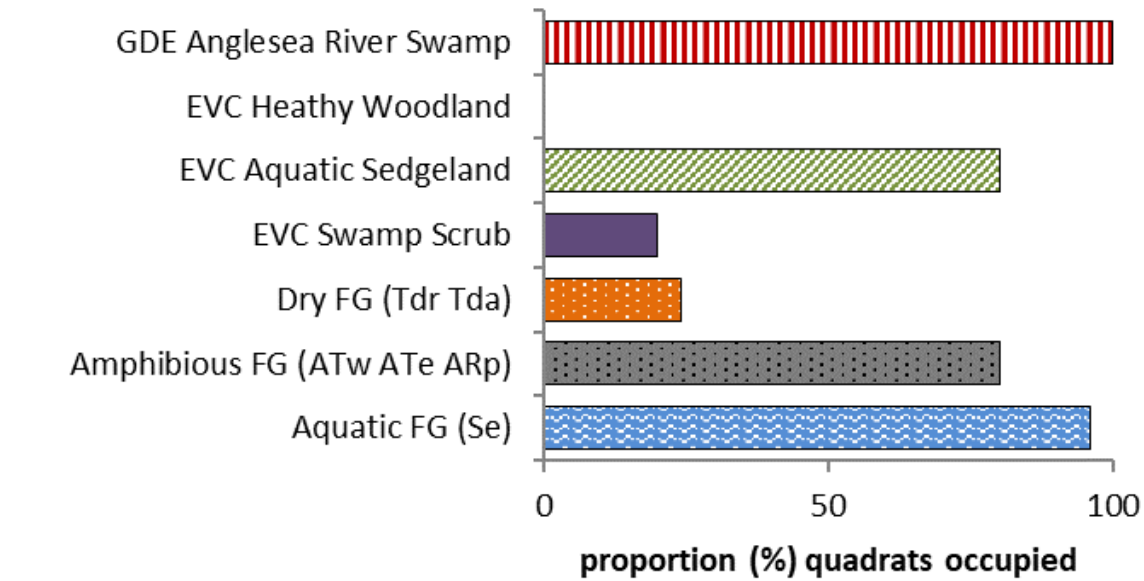
Figure 10 Anglesea Borefield Monitoring and Assessment Program, Anglesea Swamp, Site AS1_2014, vegetation summary data, 2020.

AS1_2014: General habitat description					
Ecological Vegetation Class (EVC)			Aquatic Sedgeland		
Wetland permanence			Ephemeral		
Mostly open swamp almost completely fringed with Scented Paperbark and Prickly Tea-tree consisting of 70–100%. Considerable amounts of floating filamentous algae. Emergent rushes (20–50%) are located throughout the swamp, and submergent thin water ribbon (< 5%). Some evidence of wallaby tracks and carnivore scats also present.					
AS1_2014: Frog abundance and richness					
Southern Brown Tree Frog		Common Froglet		Southern Bullfrog	Species Richness
0		0		0	0
AS1_2014: Water quality parameters					
Survey 1					
pH	5.05	Turbidity	0 NTU	Water temperature	19.8 °C
EC	3.40 µs/cm	Salinity	0.17%	Dissolved Oxygen	9.17 mg/L
Survey 2					
pH	8.31	Turbidity	0 NTU	Water temperature	21.8 °C
EC	0.02 µs/cm	Salinity	3.93%	Dissolved Oxygen	7.23 °C
Comments					
The depth of the swamp by the second frog survey was still suitable for water quality measurements. One Southern Bullfrog was calling very infrequently during the first survey, at least 100 m from observers. An Owlet nightjar and Southern boobook heard calling during second frog survey. There were no frogs detected in either survey.					

Figure 11 Anglesea Borefield terrestrial revised ecological Monitoring and Assessment Program, Anglesea Swamp site AS1_2014, 2019 frog summary data.



Proportion of EVCs and broad FGs, Site AGP_2014



Key:
GDE: Groundwater Dependent Ecosystem
EVC: Ecological Vegetation Class
FG: Functional Group

Dominant Plant Species	Broad FG	Quadrats occupied (% frequency)
<i>Cycnogeton procerum</i> sp. aff.	Common Water-ribbons	Aquatic 96
<i>Melaleuca squarrosa</i> .	Scented Paperbark	Amphibious 50
<i>Juncus procerus</i>	Tall Rush	Amphibious 36

Other attributes		
Average % bare ground cover	40	(bare ground recorded in 50 quadrats)
Average water depth along transect (cm)	16.5	Water recorded in 50 quadrats
Algal mat (quadrats occupied)	30	

Figure 12 Anglesea Borefield Monitoring and Assessment Program, Anglesea Swamp, Site AGP2_2014, vegetation summary data, 2020.

AGP2_2014: General habitat description					
Ecological Vegetation Class (EVC)			Aquatic Sedgeland		
Wetland permanence			Ephemeral		
This is a small (c. 0.25 ha) clearing in tall (up to 4 m) fringing vegetation of Scented Paperbark and Prickly Tea-tree (70-100%). Approximately 40% open water with 50–70% cover of floating Common Water-ribbons, interspersed with emergent rushes (<i>Juncus</i> spp.) and patches of Scented Paperbark. Emergent vegetation consisted of <i>Gahnia</i> , Common Water-ribbon, and rushes (50-70%), with submergent Common Water-ribbon.					
AGP2_2014: Frog abundance and richness					
Southern Brown Tree Frog		Common Froglet		Southern Bullfrog	Species Richness
0		0		0	0
AGP2_2014: Water quality parameters					
Survey 1					
pH	5.38	Turbidity	2 NTU	Water temperature	17.7 °C
EC	3.27 µs/cm	Salinity	0.16%	Dissolved Oxygen	6.02 mg/L
Survey 2					
pH	5.35	Turbidity	0 NTU	Water temperature	19.7 °C
EC	3.41 µs/cm	Salinity	0.17%	Dissolved Oxygen	2.56 mg/L
Comments					
No frogs were detected calling in either survey.					

Figure 12 Anglesea Borefield terrestrial revised ecological Monitoring and Assessment Program, Anglesea Swamp site AGP2_2014, 2019 frog summary data.

AS5: General habitat description					
Ecological Vegetation Class (EVC)			Aquatic Sedgeland		
Wetland permanence			Ephemeral		
The small (0.25 ha) section of swamp was generally moist with occasional deeper depressions. The vegetation, consists sedges and Pouched Coral-fern, surrounded by 70-100% cover of fringing Prickly Tea-tree and Scented Paperbark. There is a thick cover of emergent dead sedges and 10% cover of fallen branches around the perimeter of the swamp.					
AS5: Frog abundance and richness					
Southern Brown Tree Frog		Common Froglet		Southern Bullfrog	Species Richness
0		0		0	0
AS5: Water quality parameters					
Survey 1					
pH	3.84	Turbidity	0 NTU	Water temperature	13.3°C
EC	2.58 µs/cm	Salinity	0.12%	Dissolved Oxygen	1.55 mg/L
Survey 2					
pH	NA	Turbidity	NA	Water temperature	NA
EC	NA	Salinity	NA	Dissolved Oxygen	NA
Comments					
The swamp was mostly moist throughout with the occasional deeper depression (0.05 m) during the first frog survey. Depth had declined by the second frog survey precluding water quality measurements. A Southern boobook owl was heard calling during the first frog survey. No frogs were detected in either nocturnal survey.					

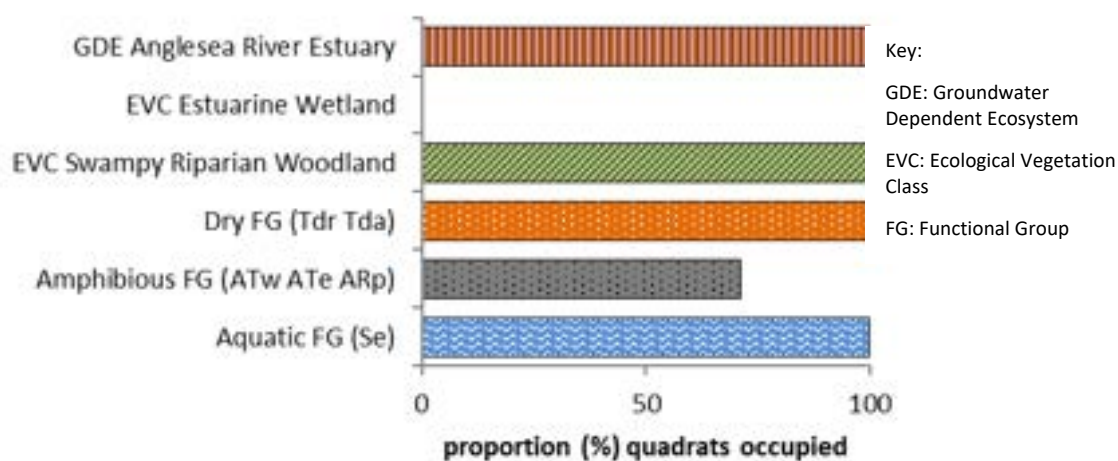
Figure 13 Anglesea Borefield terrestrial revised ecological Monitoring and Assessment Program, Anglesea Swamp site AS5, 2020 frog summary data.

AS6: General habitat description					
Ecological Vegetation Class (EVC)			Aquatic Sedgeland		
Wetland permanence			Ephemeral		
Swamp relatively shallow (to 0.1 m) consisting of emergent (20–50%) vegetation consisting of decomposing sedges, small clumps of live sedges and Scented Paperbark. There are small (10-20%) amounts of submergent and floating vegetation consisting of sedges and algae. The swamp is fringed by 70–100% cover of Scented Paperbark. The swamp perimeter supports <5% cover of fallen branches and 5–10% cover of bare soil. Small runnels contain dead vegetation, algae and live sedges.					
AS6: Frog abundance and richness					
Southern Brown Tree Frog		Common Froglet		Southern Bullfrog	Species Richness
0		0		0	0
AS6: Water quality parameters					
Survey 1					
pH	5.14	Turbidity	7 NTU	Water temperature	18.8°C
EC	3.25 µs/cm	Salinity	0.17%	Dissolved Oxygen	4.65 mg/L
Survey 2					
pH	NA	Turbidity	NA	Water temperature	NA
EC	NA	Salinity	NA	Dissolved Oxygen	NA
Comments					
Water quality was not measured during the second survey event due to insufficient depth. Southern brown tree-frog was detected calling about 200 m from the site during the second frog survey.					

Figure 14 Anglesea Borefield terrestrial revised ecological Monitoring and Assessment Program, Anglesea Swamp site AS6, 2019 frog summary data.



Proportion of EVCs and broad FGs, Site LAR1



Dominant native plant species		Broad FG	Quadrats occupied (% frequency)
<i>Cynogeton procerum</i> sp. aff.	Common Water-ribbons	Aquatic	100
<i>Eucalyptus ovata</i> var. <i>ovata</i>	Swamp Gum	Dry	100
<i>Juncus kraussii</i> ssp. <i>australiensis</i>	Sea Rush	Aquatic	57
<i>Leptospermum scoparium</i>	Manuka	Dry	57
Other attributes			
Average % bare ground cover			0
Algal mat			2

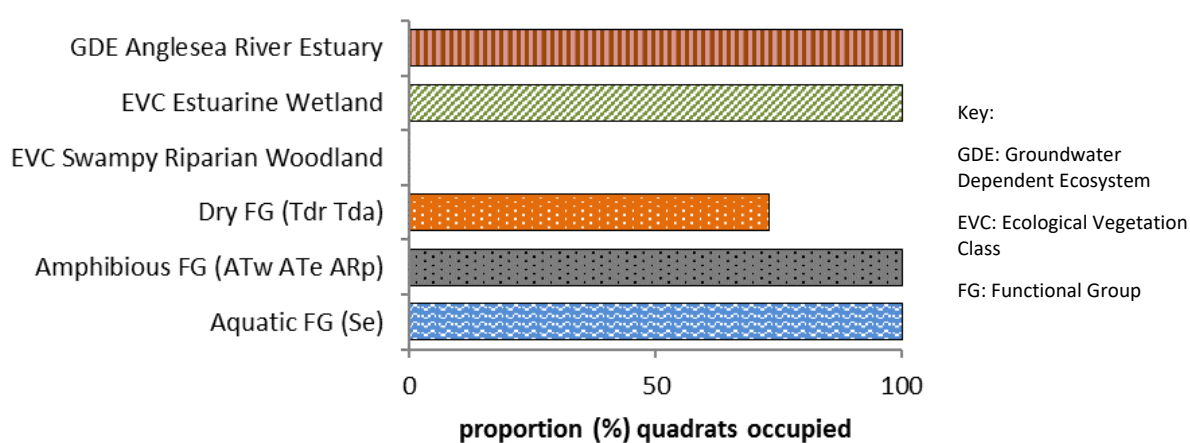
Figure 15 Anglesea Borefield Monitoring and Assessment Program, Anglesea Estuary, Site LAR1, vegetation summary data, 2020

LAR1: General habitat description					
Ecological Vegetation Class (EVC)			Swampy Riparian Woodland		
Wetland permanence			Permanent		
This site is a section of slow-flowing creek 30–100 cm deep and 3-4 m wide, with 50–70% presence of submergent vegetation consisting of algae and Southern Water-ribbons and 20-50% cover of floating water-ribbons. The creek is fringed with young Common Reeds, water-ribbons and revegetation in the form of Prickly Tea-tree, Eucalypts and Goodenia. Common Reeds are an emergent vegetation along the banks.					
LAR1: Frog abundance and richness					
Southern Brown Tree Frog		Common Froglet		Southern Bullfrog	Species Richness
0		0		0	0
LAR1: Water quality parameters					
Survey 1					
pH	5.36	Turbidity	3 NTU	Water temperature	15.2 °C
EC	4.04 µs/cm	Salinity	0.2%	Dissolved Oxygen	5.76 mg/L
Survey 2					
pH	4.11	Turbidity	1 NTU	Water temperature	18.4 °C
EC	4.04 µs/cm	Salinity	0.2%	Dissolved Oxygen	5.56 mg/L
Comments					
During the second frog survey Common froglet (1-5 individuals), Pobblebonk (1-5 individuals), and Southern Brown Tree Frogs (1–5 individuals) were detected calling from more than 100 m upstream of the site.					

Figure 16 Anglesea Borefield terrestrial revised ecological Monitoring and Assessment Program, Anglesea Estuary site LAR1, 2020 frog summary data.



Proportion of EVCs and broad FGs, Site LAR2



Dominant native plant species		Broad FG	Quadrats occupied (% frequency)
<i>Juncus kraussii</i> ssp. <i>australiensis</i>	Sea Rush	Aquatic	100
<i>Lobelia anceps</i>	Angled Lobelia	Amphibious	93
<i>Phragmites australis</i>	Common Reed	Amphibious	93

Other attributes	
Average % bare ground cover	1
Algal mat	0

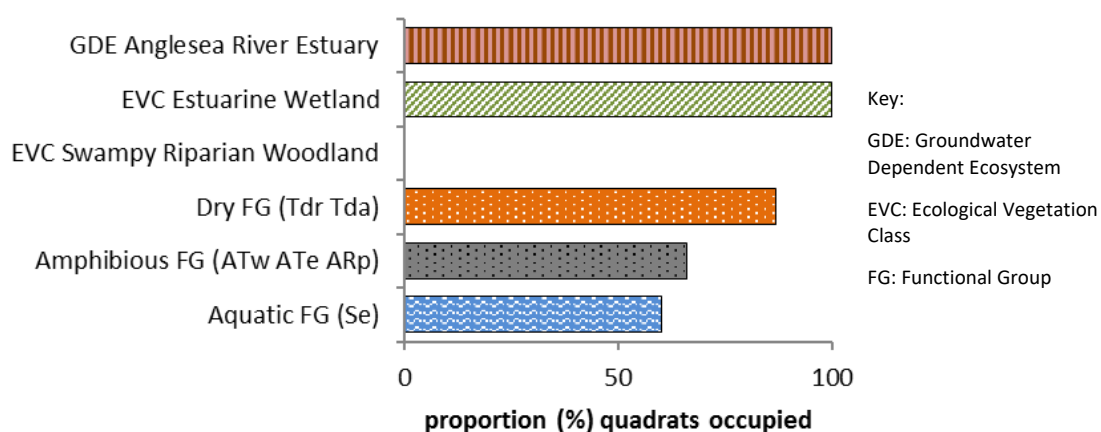
Figure 17 Anglesea Borefield Monitoring and Assessment Program, Anglesea Estuary, Site LAR2, vegetation summary data, 2020.

LAR2: General habitat description					
Ecological Vegetation Class (EVC)			Estuarine Woodland		
Wetland permanence			Permanent		
Slow-moving creek in estuary 2 – 3 m deep and 7 m wide, fringed with 50–70% cover of Angled Lobelia, Coastal Tussock-grass, Sea Rush and Common Reed. The submergent vegetation comprises 5–10% cover at edge of channel consisting of dead reeds and algae. Floating vegetation consists of 5–10% water ribbon. The site is mostly open, supporting less than 5% cover of emergent vegetation.					
LAR2: Frog abundance and richness					
Southern Brown Tree Frog		Common Froglet		Southern Bullfrog	Species Richness
0		0		1	1
LAR2: Water quality parameters					
Survey 1					
pH	3.68	Turbidity	4 NTU	Water temperature	21.2 °C
EC	10.9 µs/cm	Salinity	0.59%	Dissolved Oxygen	9.3 mg/L
Survey 2					
pH	3.78	Turbidity	5 NTU	Water temperature	22.8 °C
EC	9.8 µs/cm	Salinity	0.55%	Dissolved Oxygen	7.26 mg/L
Comments					
Southern Bullfrogs (5–10) were heard and observed calling during both surveys, with distant individual heard calling up to 100 m from observers.					

Figure 18 Anglesea Borefield terrestrial revised ecological Monitoring and Assessment Program, Anglesea Estuary site LAR2, 2020 frog summary data.



Proportion of EVCs and broad FGs, Site LAR3



Dominant native plant species		Broad FG	Quadrats occupied (% frequency)
<i>Poa poiformis</i> var. <i>poiformis</i>	Coast Tussock-grass	Dry	73
<i>Juncus kraussii</i> ssp. <i>australiensis</i>	Sea Rush	Aquatic	60
<i>Leptosperum scoparium</i>	Manuka	Dry	60

Other attributes		
Average % bare ground cover		0
Algal mat		0

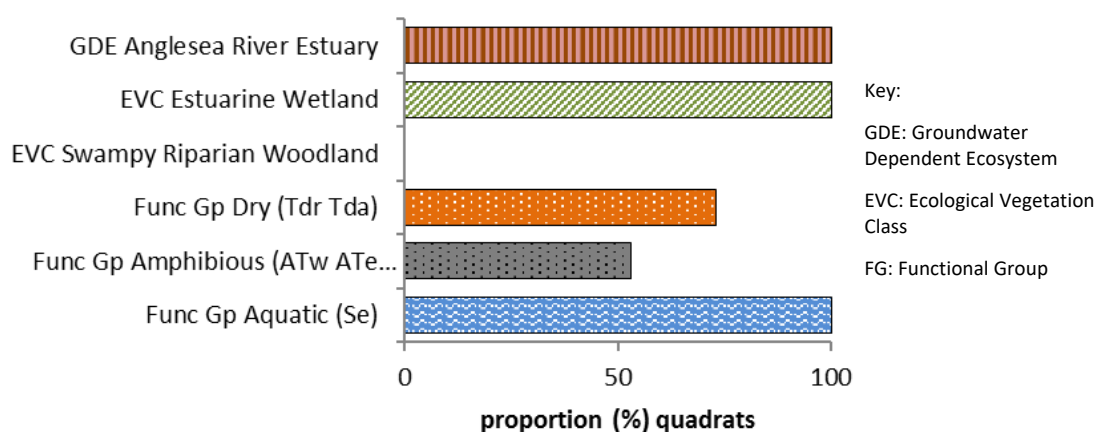
Figure 19 Anglesea Borefield Monitoring and Assessment Program, Anglesea Estuary, Site LAR3, vegetation summary data, 2020.

LAR3: General habitat description							
Ecological Vegetation Class (EVC)			Estuarine Woodland				
Wetland permanence			Permanent				
Slow-flowing creek up to 10 m wide and up to 2–3 m deep. There is 5–10% floating and 5–10% submergent vegetation, comprising of mainly Sedges and algae, Common Water-ribbons and Common Reeds. There is a nominal (5–10%) cover of emergent reeds and water-ribbons along the banks. The banks also contain a cover of bare soil, debris and fallen branches. The site is fringed by 70–100% cover of vegetation including Sea Rush, Common Water-ribbons and Shiny Swamp-mat.							
LAR3: Frog abundance and richness							
Southern Brown Tree Frog		Common Froglet		Southern Bullfrog		Species Richness	
1		0		1		2	
LAR3: Water quality parameters							
Survey 1							
pH	4.53	Turbidity	3 NTU	Water temperature		18.6 °C	
EC	5.96 µs/cm	Salinity	0.34%	Dissolved Oxygen		7.36 mg/L	
Survey 2							
pH	3.61	Turbidity	4 NTU	Water temperature		21.9 °C	
EC	9.2 µs/cm	Salinity	0.51%	Dissolved Oxygen		8.84 mg/L	
Comments							
Southern Brown Tree Frogs (1–5) were heard calling from within 100 m of observers. Southern Bullfrog were observed floating in the creek and heard calling along the path during both surveys.							

Figure 20 Anglesea Borefield terrestrial revised ecological Monitoring and Assessment Program, Anglesea Estuary site LAR3, 2020 frog summary data.



Proportion of EVCs and broad FGs, Site LAR4



Dominant native plant species		Broad FG	Quadrats occupied (% frequency)
<i>Poa poiformis</i> var. <i>poiformis</i>	Coast Tussock-grass	Dry	73
<i>Juncus kraussii</i> ssp. <i>australiensis</i>	Sea Rush	Aquatic	60
<i>Leptosperumum scoparium</i>	Manuka	Dry	60

Other attributes		
Average % bare ground cover		0
Algal mat		0

Figure 21 Anglesea Borefield Monitoring and Assessment Program, Anglesea Estuary, Site LAR4, vegetation summary data, 2020.

LAR4: General habitat description					
Ecological Vegetation Class (EVC)			Heathy Woodland		
Wetland permanence			Permanent		
This wide (<10 m) section of creek is up to 3 m deep and is fringed by revegetation (70–100%) along the west bank consisting of: Goodenia, Prickly Tea-tree, etc. The east bank is revegetated with Sea Rush, dead Common Reed and Coastal Tussock-grass. There are dense submerged algal mats along the bank and decomposing and emergent sedges and reeds. Low floating submergent vegetation (5–10%) consists of Common Water-ribbons, Sea Rush, algae and dead vegetation.					
LAR4: Frog abundance and richness					
Southern Brown Tree Frog		Common Froglet		Southern Bullfrog	
1		0		1	
				2	
LAR4: Water quality parameters					
Survey 1					
pH	3.83	Turbidity	4 NTU	Water temperature	20.8 °C
EC	10.4 µs/cm	Salinity	0.58%	Dissolved Oxygen	10.63 mg/L
Survey 2					
pH	3.73	Turbidity	4 NTU	Water temperature	22.4 °C
EC	8.39 µs/cm	Salinity	0.46%	Dissolved Oxygen	6.53 mg/L
Comments					
Southern Brown Tree Frogs (1–5) and Southern Bullfrogs (1–5) were heard calling during the second survey, at least 100 m from observers.					

Figure 22 Anglesea Borefield terrestrial revised ecological Monitoring and Assessment Program, Anglesea Estuary site LAR4, 2020 frog summary data.



Figure 23 Anglesea Borefield ecological Monitoring and Assessment Program, wetland boundaries, sites AS2, AS3 and AS4, Anglesea Swamp 2020.



Figure 24 Anglesea Borefield ecological Monitoring and Assessment Program, wetland boundaries, sites ASP7_2014, AS1_2014 NS AGP2_2014, Anglesea Swamp 2020.

3.3 Macroinvertebrates

The macroinvertebrate results based on combined sample data from each site are provided in Table 7, for comparison against previous results (GHD 2010–2017, Ecology Australia 2018–2019).

None of the samples collected contained sufficient macroinvertebrates to enable the sample to be picked in 30 minutes (each one had less than 200 macroinvertebrates in total across all three edge samples). At the time of sampling, BCT1 had very low surface water, however, three edge samples were still collected.

Site SC1 was considerably more diverse (i.e. a higher number of taxa) than sites W2/3 and BCT1 (Table 7). However, all three sites detected fewer taxa than the objective listed in the State Environmental Protection Policy – Waters objective (SEPP (W); Vic. Gov. 2018; Table 7). Sites SC1 and BCT1 achieved the SEPP (W) goal for SIGNAL score, however, site W2/3 did not. Both SC1 and BCT1 recorded a total of five EPT taxa, which is one short of the SEPP (W) objective, while no EPT taxa were detected at site W2/3 (Table 7). Overall, only two of a possible 12 objectives were met during the 2020 macroinvertebrate monitoring, with the overall objective attainment result being comparable to the 2019 result (Ecology Australia, 2020). Individual sample results from each site are presented in section 3.7.

Table 7 Site macroinvertebrate indices result from combined samples (non-attainment of SEPP (W) objectives indicated by shading)

Index	W2/3	SC1	BCT1	SEPP (W) objective*
# taxa	6	19	9	20
SIGNAL score	3.0	4.3	4.8	3.4
EPT	0	5	5	6*
EPTO	0	5	5	-

*Indicates an objective that was sourced from the previous report (Ecology Australia 2020) because no applicable objective exists in the current SEPP (W).



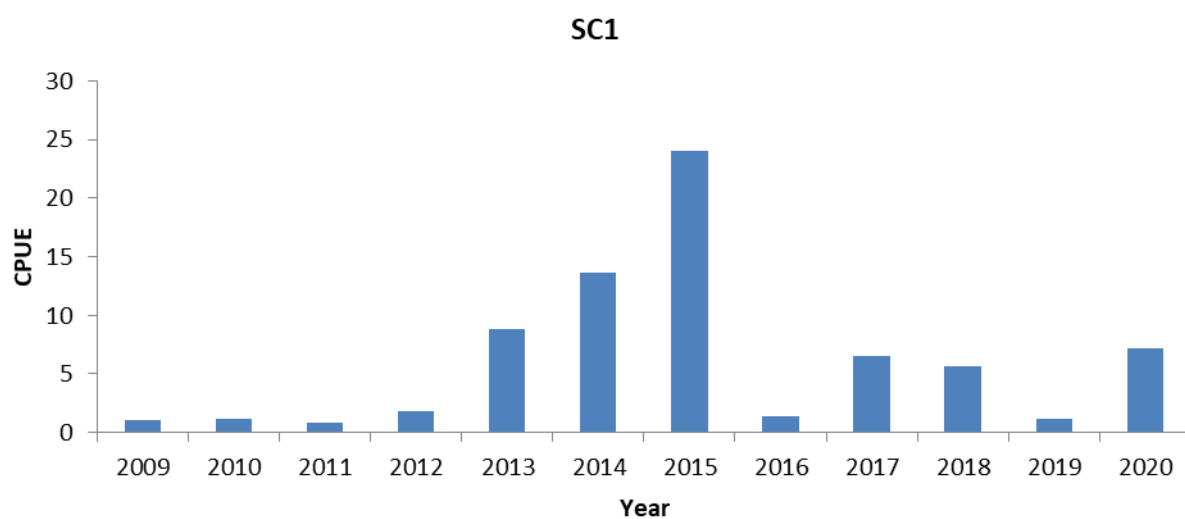
Plate 2 Leptoceridae (*Lectrides* sp.) outside its case, collected from site SC1 during the 2020 survey.

3.4 Southern Pygmy Perch

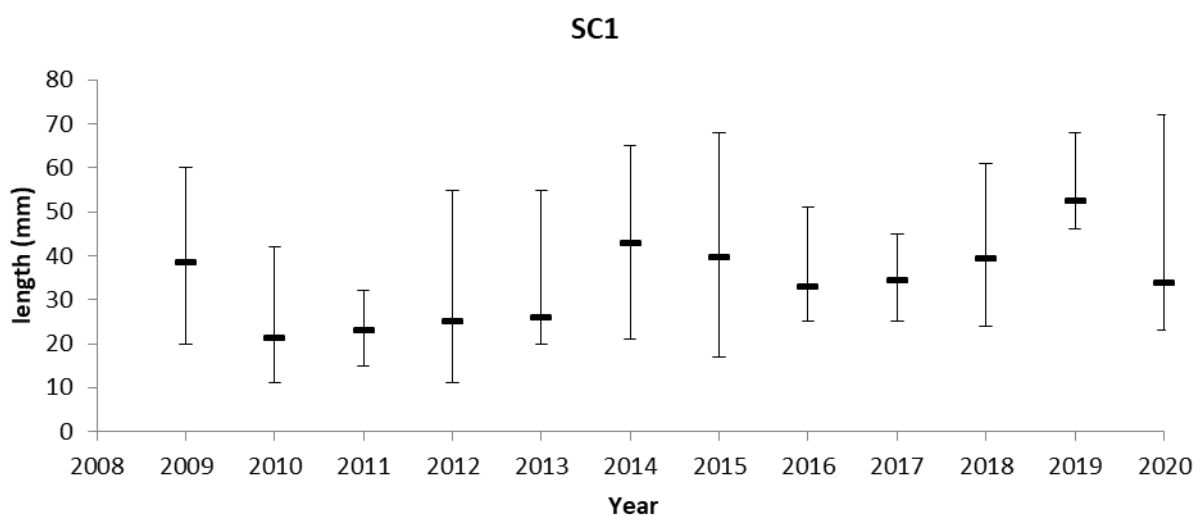
A total of 72 Southern Pygmy Perch were captured from Salt Creek (SC1), and none were captured from Breakfast Creek tributary (BCT1; Figure 25; Figure 26; and Plate 4). The Southern Pygmy Perch Catch Per Unit Effort (CPUE) from Salt Creek was the highest since 2015 (the highest year recorded) and represents the fourth-highest rate since 2009. Young of year fish (i.e. fish considered to be less than one year of age) were also detected at SC1, which indicates that fish are continuing to recruit within this system, despite a lack of recruitment evident in 2019. This year's sampling (2020) was the third consecutive year that Southern Pygmy Perch were not recorded at the Breakfast Creek tributary site.



Plate 3 Southern Pygmy Perch from SC1.

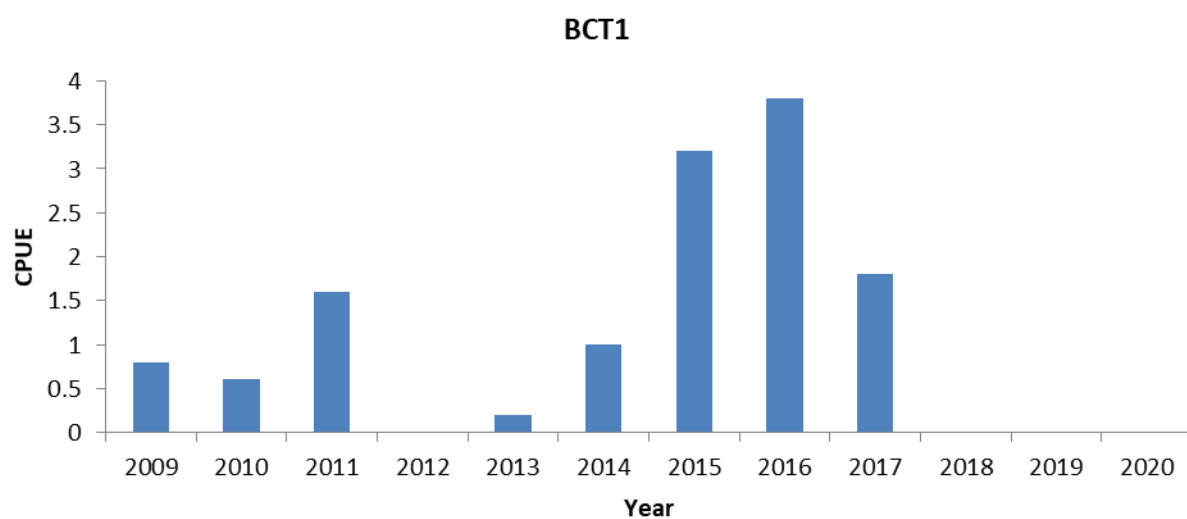


a) Fish Catch Per Unit Effort (CPUE; fish per trap) at site SC1.

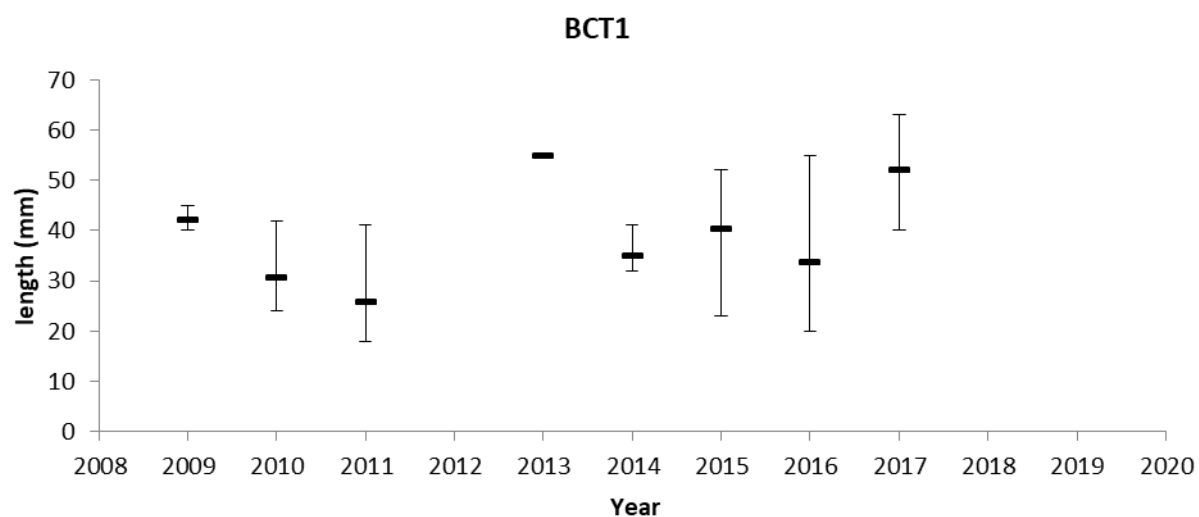


b) Mean (black bars), together with minimum and maximum lengths (TL) of Southern Pygmy Perch.

Figure 25 Site SC1 Southern Pygmy Perch spring CPUE (a), and length (b) summary 2009–2020.



a) Fish Catch Per Unit Effort (CPUE; fish per trap) at BCT1.



b) Mean (black bars), together with minimum and maximum lengths (TL) of Southern Pygmy Perch.

Figure 26 Site BCT1 Southern Pygmy Perch spring CPUE (a), and length (b) summary 2009–2020.

3.5 Water quality

Water quality results were fairly consistent with results from previous years (GHD 2010–17, Ecology Australia 2018–2020; Table 8). It should be noted that to accurately assess against SEPP (W) indices, a minimum of 11 data points are required from a single year, hence snap-shot measurements are incapable of indicating compliance. The SEPP (W) objectives are compared against the results only to provide context. For sites BCT1 and SC1, the SEPP (W) was potentially met for conductivity but not for dissolved oxygen or pH, while site W2/3 possibly did not meet any objective.

Table 8 In situ water quality results and SEPP (W) objectives (potential non-attainment of SEPP (W) objectives indicated by shading).

	Temperature (°C)	Conductivity (s/cm)	Dissolved oxygen		pH
			mg/L	%Sat	
SEPP (W) objective		≤2000 (75 th percentile)		≥70 (25 th percentile)	6.8-8 (25 th -75 th percentile)
BCT1	11.2	310	4.3	40.2	4.2
SC1	12.5	285	3.7	35.6	4.9
W2/3	12.9	4130	6.1	60.5	2.4

3.6 Otway Bush Yabby

Otway Bush Yabby *Geocharax tasmanicus* is a small freshwater crayfish listed as Endangered on the Victorian Advisory List of threatened invertebrates (DSE 2009). Otway Bush Yabby was detected at two of the three surveys locations where the species has been detected annually since 2017 (Ecology Australia 2018–2020). Otway Bush Yabby was detected during both the fish survey (bait trapping) and the macroinvertebrate sampling (sweep sampling; Table 9). A total of 86 Otway Bush Yabbies were detected at site BCT1 and 94 at site SC1 during the 2020 sampling. This represents a total of 180 Otway Bush Yabbies, nearly three times the amount detected in 2019. As in previous years, Otway Bush Yabby was not detected at site W2/3.

Table 9 Records of Otway Bush Yabby (spring 2020).

Site	Macroinvertebrate sampling	Bait trapping
BCT1	81	5
SC1	20	74
W2&3	0	



Plate 4 Otway Bush Yabby – Salt Creek (SC1)



Plate 5 Otway Bush Yabbies – Breakfast Creek tributary (BCT1)

3.7 Aquatic monitoring sites

Wetland 2 and 3



Plate 6 Wetland 2 and 3

At the time of the survey, Wetlands 2 and 3 were very shallow, contracted, and dominated by dense stands of Paperbark and Tea-tree. The dominant aquatic vegetation taxa were *Triglochin* spp.

The substrate was predominantly clay/silt, with a gravel track running adjacent to the site and presenting a potential point source of pollutants and sediment. Filamentous algae were highly abundant, and macrophytes and coarse particulate organic matter were present in moderate abundance. The majority of the site exhibited no obvious flow, with only a small area of slow flow being evident within a small channel crossing under the track. Despite combining the two wetlands (ref to section 2.3.1), this site had very limited standing water.

The macroinvertebrate results for the wetland site were poor (See Table 6 and Table 10). Overall, the macroinvertebrate abundance and diversity was very low, however, edge sample two and three achieved the desired SIGNAL score. Despite this, the overall SIGNAL score for W2/3 did not achieve the SIGNAL score goal (refer to Table 6). Macroinvertebrate sampling results from Wetland 2/3 were broadly similar to the most recent survey in 2019 (Ecology Australia 2020). No Otway Bush Yabby was detected at W2/3 in 2020 (Note: they have not been previously detected at this site).

Table 10 Individual macroinvertebrate sample results at W2/3, showing SEPP (W) objectives (shading indicates non-attainment of SEPP (W) objectives)

Metric	W2/3			SEPP (W) objective
	Edge sample 1	Edge sample 2	Edge sample 3	
# taxa	5	1	3	20
Abundance	35	6	38	-
SIGNAL2	3.0	6.0	3.7	3.4
EPT	0	0	0	6*
EPTO	0	0	0	-

*Indicates where the metric from the previous report and not the SEPP (W) was used.

Salt Creek (SC1)



Plate 7 Salt Creek at SC1

Salt Creek at SC1 had the largest areas of surface water available for sampling and appeared permanent. The substrate was silt/clay, and the site was dominated by lentic (still) habitats. The main instream cover available for fish and macroinvertebrates, in decreasing order of prevalence, consisted of loose silt lying on the surface, Coarse Particulate Organic Matter (CPOM; e.g. leaves, branches and other organic debris), overhanging terrestrial vegetation, aquatic vegetation, overhanging bank and logs. The dominant aquatic vegetation taxa were *Juncus* spp. and *Carex* spp.

Salt Creek attained SEPP (W) objectives for SIGNAL score for all three edge samples, however, did not attain SEPP (W) goals for all other indices (Table 11). Snapshot water quality appeared to be suitable for fish and crayfish although the results may potentially fail to meet the dissolved oxygen and pH goals. Strong numbers of Otway Bush Yabby were detected at SC1 with a total of 94 individuals detected across the two sampling methods used. This represents a significant increase in the number of Otway Bush Yabby detected at SC1 compared with the 4 detected in 2019.

Table 11 Individual macroinvertebrate sample results at SC1, showing SEPP (W) objectives (shading indicates non-attainment of SEPP (W) objectives)

Metric	SC1			SEPP (W) objective
	Edge sample 1	Edge sample 2	Edge sample 3	
# taxa	11	5	14	20
Abundance	40	21	112	-
SIGNAL2	4.9	5.0	4.0	3.4
EPT	3	1	4	6*
EPTO	3	1	4	-

The abundance of Southern Pygmy Perch at SC1 was the highest recorded since 2015. The length frequency histogram shows two distinct cohorts, those larger and older fish, around 70–75 mm and those younger fish around 25–40 mm. During the 2019 sampling only older and larger fish were detected, a potential indication of short term recruitment failure. However, the 2020 length data clearly shows that strong recent recruitment in the system has occurred and that the population size may now be slightly larger than it has been over the last five years. Southern Pygmy Perch typically reach maturity at approximately 30–33 mm (conservatively set at 30 mm for the histogram; Knight 2008) with the smallest length detected being smaller than 30 mm, indicating that young of year fish are likely to be present within the system.

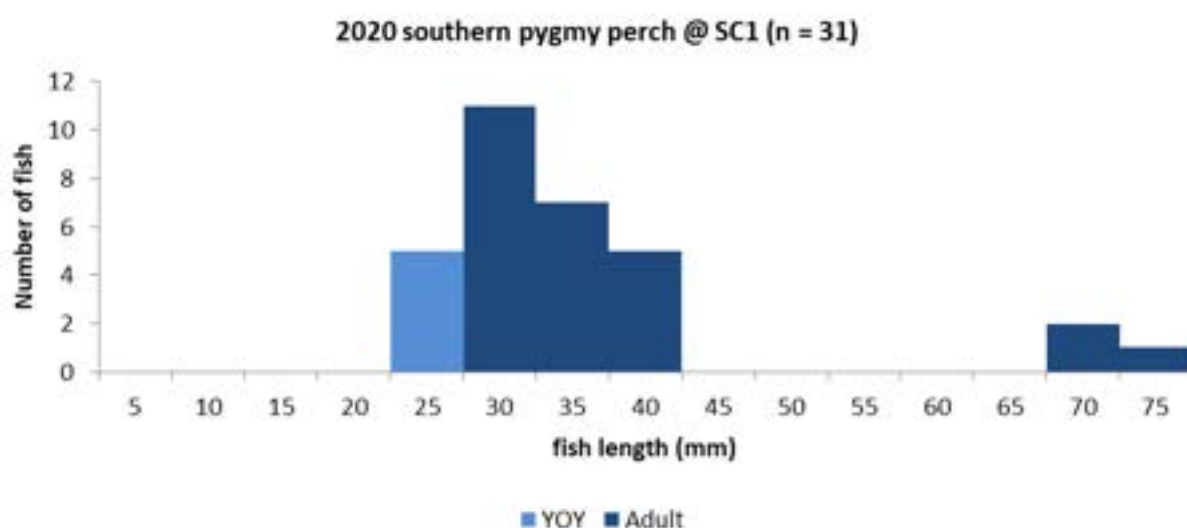


Figure 27 Length-frequency histogram of Southern Pygmy Perch at SC1 showing two distinct cohorts.

Breakfast Creek tributary 1 (BCT1) at SV3

Plate 8 Breakfast Creek tributary BCT1, showing stream gauge

Breakfast Creek tributary at site BCT1 consisted of a narrow, shallow stream, with a maximum width of 1.5 m. During the 2020 surveys, BCT1 was near dry with very slow flow only occurring adjacent to the stream gauge (over the small weir). Longitudinally the stream was a series of disconnected and/or poorly connected pools along the length of the surveyed reach. During the 2020 survey, 10 bait traps were set and three macroinvertebrate sweeps were taken. However, the length of reach was extended from that described in the 2019 report to account for the shallow, near dry prevailing habitat. The substrate was predominantly silt/clay, with some sand, pebble and gravel present. The main instream cover available for fish and macroinvertebrates, in decreasing order of prevalence, consisted of coarse particulate organic matter (e.g. leaves and other organic debris), overhanging terrestrial vegetation, loose silt lying on the surface, overhanging bank, woody debris, filamentous algae, roots, and moss.

The macroinvertebrate survey of BCT1 showed that this site attained SEPP (W) objectives for SIGNAL scores for two of three edge samples (Table 12). No other SEPP (W) objectives were achieved at BCT1 either on a sample basis or site/combined sample basis (see Table 6). The overall abundance of macroinvertebrates during the 2020 survey was low, however, it is a promising sign that EPT taxa remain and make up a large proportion of the taxa present. Snapshot water quality appeared to be suitable for fish and crayfish although the results may potentially fail to meet the dissolved oxygen and pH objectives. Strong numbers of Otway Bush Yabby were detected at BCT1 with a total of 86

individuals detected across the two sampling methods used. This represents an increase in the 57 Otway Bush Yabbies detected at BCT1 in 2019 (Ecology Australia 2020).

Table 12 Individual macroinvertebrate sample indices result at BCT1, showing SEPP (W) objectives (shading indicates non-attainment of SEPP (W) objectives)

Metric	BCT1			SEPP (W) objective
	Edge sample 1	Edge sample 2	Edge sample 3	
# taxa	5	1	6	20
Abundance	14	1	20	-
SIGNAL2	6.2	6.0	3.3	3.4
EPT	4	1	2	6*
EPTO	4	1	2	-

No Southern Pygmy Perch were detected at BCT1 during this round of monitoring. This is the third year in a row that this species has not been detected at BCT1. Previous reports have highlighted that there may have been a recruitment failure at this site in 2017.

4 Discussion

4.1 Vegetation

Overall, there appeared to be little change in vegetation health in the swamp and estuary in 2020 compared with previous years under the current MAP.

The recorded EVCs at each site did not vary from previous years in the Anglesea Swamp and Estuary (see Ecology Australia 2014–2019). Similarly, plant diversity across functional groups showed little change and continued to be dominated by aquatic and amphibious Functional Groups at every site in the Anglesea Swamp and Estuary (see Ecology Australia 2014–2019). However there does appear to be an emerging trend of change in percentage frequency of five wetland species across four of the Anglesea Swamp sites. The two hydro-ecological functional groups that are represented in this trend are ATe represented by Tall Rush at site AGP_2014 and Se represented by Fine Twig-sedge, Square Twig-sedge, Tall Spike-sedge and Water Ribbons.

The observable decline in health of one species in the ATe functional group at site AGP_2014 would suggest that the growth tolerance of the species at the site has been exceeded. Using the descriptions of the functional group (Table 1) this could indicate that the site has received less than 8 months of inundation of water on an annual basis since. This appears to generally coincide with a number of very dry years for rainfall. It is important to note that there are other variables that can affect plant health such as soil and water salinity and acidity.

The general trend of decline across multiple species, in particular Tall Spike-sedge, Fine Twig-sedge and Square Twig-sedge from the Se functional group suggests that there has been an increased drying out of the root-zones of these plants during the dry periods over multiple years. Again, this is consistent with the more recent lower rainfall years. One species Water Ribbons from the same functional group (Se) showed a more variable (temporal and spatial) changes in percentage frequency which could be a function of the plant's biology differences.

Total plant species numbers varied little from previous years in the swamp (Table 12) and the estuary (Table 13) and the differences are within the expected range of natural seasonal variation.

Table 13 Total plant numbers and number of plant species in Functional Groups at study sites in the Anglesea Swamp, Anglesea Borefield Monitoring and Assessment Program, 2020.

Anglesea Swamp Transect/ Site	Year	Total number of native species	Number of plant species in Functional Group Dry (Tdr, Tda)	Number of plant species in Functional Group Amphibious (ATI, ATe, ATw; and Arp)	Number of plant species in Functional Group Aquatic (Se)
AS2	2014	13	9	2	2
	2015	13	8	2	3

Anglesea Swamp Transect/ Site	Year	Total number of native species	Number of plant species in Functional Group Dry (Tdr, Tda)	Number of plant species in Functional Group Amphibious (ATI, ATe, ATw; and Arp)	Number of plant species in Functional Group Aquatic (Se)
	2016	15	9	2	4
	2017	16	10	2	4
	2019	15	9	4	2
	2020	13	7	4	2
AS3	2014	13	3	8	2
	2015	13	3	8	2
	2016	11	3	7	1
	2017	11	3	7	1
	2019	10	2	7	1
	2020	10	2	7	1
AS4	2014	21	9	9	3
	2015	22	9	9	4
	2016	21	8	10	3
	2017	20	8	9	3
	2019	16	4	9	3
	2020	15	3	9	3
ASP7_2014	2014	16	2	10	4
	2015	16	1	10	5
	2016	17	3	10	4
	2017	17	3	10	4
	2019	15	3	10	2
	2020	14	3	9	2
AS1_2014	2014	14	4	7	3
	2015	14	4	7	3
	2016	12	3	7	2
	2017	12	3	6	3
	2019	12	6	4	2

Anglesea Swamp Transect/ Site	Year	Total number of native species	Number of plant species in Functional Group Dry (Tdr, Tda)	Number of plant species in Functional Group Amphibious (ATI, ATe, ATw; and Arp)	Number of plant species in Functional Group Aquatic (Se)
	2020	12	5	4	3
AGP2_2014	2014	9	2	5	2
	2015	7	2	3	2
	2016	6	1	3	2
	2017	7	1	4	2
	2019	8	1	5	2
	2020	8	1	5	2

Table 14 Total plant numbers and number of plant species in Functional Groups at study sites in the Anglesea Estuary, Anglesea Borefield Monitoring and Assessment Program, 2020.

Anglesea Estuary Transect/ Site	Year	Total plant numbers	Number of plant species in Functional Group Dry (Tdr, Tda)	Number of plant species in Functional Group Amphibious (ATI, ATe, ATw; and Arp)	Number of plant species in Functional Group Aquatic (Se)
LAR1	2015	8	3	2	3
	2017	8	3	2	3
	2019	10	3	4	3
	2020	9	3	4	2
LAR2	2015	11	4	4	3
	2017	10	4	4	2
	2019	9	3	4	2
	2020	12	6	4	2
LAR3	2015	13	6	4	3
	2017	14	7	4	3
	2019	13	7	4	2
	2020	14	9	4	1

Anglesea Estuary Transect/ Site	Year	Total plant numbers	Number of plant species in Functional Group Dry (Tdr, Tda)	Number of plant species in Functional Group Amphibious (ATI, ATe, ATw; and Arp)	Number of plant species in Functional Group Aquatic (Se)
LAR4	2015	12	3	6	3
	2017	8	2	4	2
	2019	8	3	3	2
	2020	9	4	3	2

No weed species were recorded in the swamp. Weed species continue to be recorded in all estuary sites except LAR4 (Appendix 2). Native plant species continue to be recorded in higher numbers and higher frequencies than weeds since monitoring in the estuary began (see Ecology Australia 2015, 2017 and 2019).

There was little sign of recent disturbance in the swamp. Where the vehicle disturbance was noted at site ASP7_2014 in 2019, the aquatic vegetation appears to be re-growing and recovering.

In the swamp, the large increase in bare ground in 2020 compared to previous surveys is due to the inclusion of soil below the water surface to the total bare ground. Therefore, this increase is not comparable to previous surveys. Due to the lack of disturbance across all sites, the amount of bare ground is likely similar to that observed in 2019.

Algal mats continue to be recorded in the Anglesea Swamp (first recorded in 2016) (Figure 28). While algae are a normal part of wetland ecosystems, the growth of algae can also be associated with low flows (Mitrovic and Bowling 2013, Davie and Mitrovic 2014) and might suggest reduction of overbank flows in the swamp. At this stage there are no obvious impacts on the vegetation.

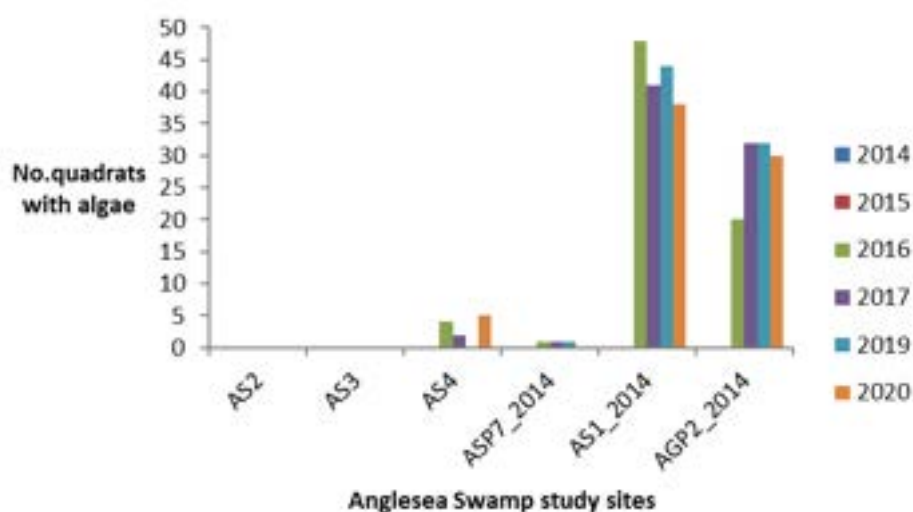


Figure 28 Algae records at study sites in the Anglesea Swamp, 2020

The 2020 climate data from the nearest weather station (Aireys Inlet ~ 10km away from Anglesea township) shows a mean annual rainfall of 620 mm from 1994–2020 (BOM 2021). Relative to this average, years with below average rainfall were 2014 (498 mm), 2015 (489 mm), 2017 (607 mm) and 2019 (525 mm). The 2016 annual rainfall (714 mm) was higher than the 1994–2020 mean (620 mm). Rainfall data was not available for 2018 (BOM 2020). The relevance of the rainfall data should be interpreted with caution given the weather station is some distance from the study sites. However, the rainfall data is useful for the purposes of demonstrating regional climatic changes which are likely to have direct influences on vegetation and algal mats.

4.2 Frogs

Results of the 2020 frog surveys as part of the Anglesea MAP are consistent with previous years, with low numbers and diversity of frogs recorded across both the Anglesea Swamp and Anglesea Estuary (Table 15, Figure 27). Although there were several individual frogs observed at the estuary sites, frogs were heard calling from more than 100 m from several survey sites, indicating that frogs occur in the greater area. The low recorded species diversity and abundance of frog species is likely correlated with the quality of frog habitat in the study area.

While hydroperiod requirements differ among the different frog species, due to specific reproductive characteristics, the presence of suitable quality water is a basic requirement for successful reproduction and tadpole metamorphosis (Hazell et al. 2003). For instance, Southern Bullfrog tadpoles typically require a period for development of up to six months to reach maturity. Hence, this species needs standing water for more than half a year for successful reproduction (Anstis 2013).

Conversely, Common Eastern Froglet tadpoles can reach maturity in only four to six weeks, and as a result can survive in small, highly intermittent waterbodies with less stable conditions (Lane and Mahony 2002; Hazell et al. 2003; Anstis 2013). During the 2020 surveys, most of the Anglesea Swamp supported standing water during the first frog survey, and while some sites reduced water levels by the second survey they had not dried out as in 2019. As such, the hydro-period at most sites should have been suitable for frog reproduction during the current survey. Frogs were recorded at four of the eight sites in 2016, a year that had above average winter/spring rainfall (587.6 mm compared to 408.1 mm on average) and 7 of the 8 sites had standing water during the first survey (Ecology Australia 2017). During the 2020 surveys a similar number of sites had standing water (8 of 8), with a similar average depth to that observed in 2016. The reduced number of frogs detected during the 2020 surveys is intriguing and is likely suggestive of the influence of a suite of long-term factors that may be impacting frog reproduction and subsequent recruitment. For instance, while conditions during the 2020 season were more conducive for frog reproduction and recruitment the low number of frogs detected across many of the survey long-term survey sites may be indicative of a lag in the rate of recovery of frogs in the greater Anglesea swamp and estuary system. Indeed, it must be acknowledged that the last couple of surveys only detected low numbers of frog number at a small number of sites. The previous surveys have consistently cited the role of reduced hydro-period for the low numbers of frogs detected, which has ultimately resulted in reproductive failure of frogs in the Anglesea swamp and estuary. Low hydro-period would affect frogs by increasing both the temperature and rate at which water evaporated,

which would have further reduced the quality and/or area of frog habitat at survey sites. Ultimately, these effects would have reduced options for frogs to breed and the likelihood that any eggs or tadpoles could hatch and successfully reach metamorphose.

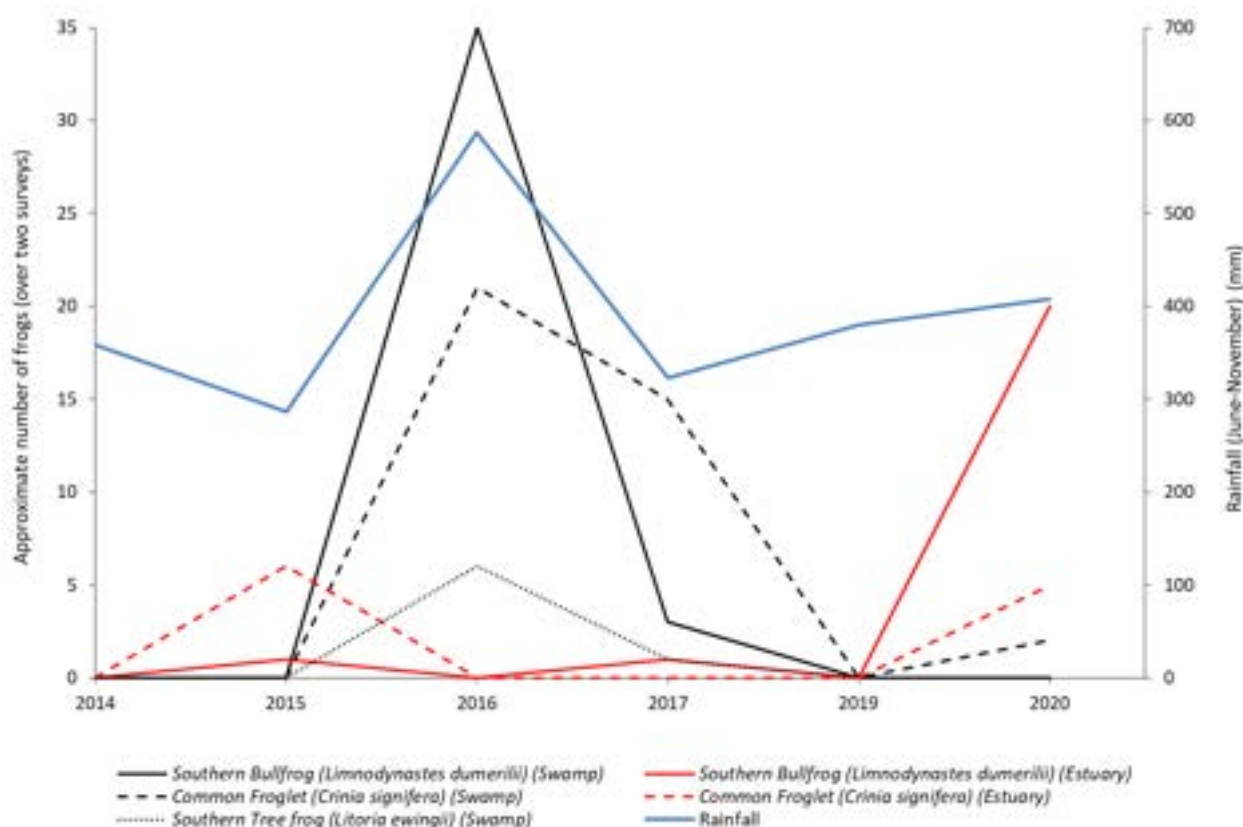


Figure 29 Approximate number of frogs recorded in spring surveys at the Anglesea Swamp and Anglesea Estuary, as part of the Anglesea Borefield Monitoring and Assessment Program, and average winter and spring rainfall, 2014–20¹. Two surveys were undertaken in each year, except for 2014, when sites were surveyed once.

Further, evidence from the water quality data suggests key water quality metrics may be impacting the quality of frog habitat. For instance, acidic water can negatively impact the survival and growth of both frog eggs and developing tadpoles. Striped Marsh Frog eggs experience 100% mortality at pH below 4.0 (Barth and Wilson 2010). Many of the sites in the Anglesea catchment exhibited acidic water metrics. While there may be species-specific differences in acidic tolerance levels, the very acidic conditions in those areas surveyed may be negatively affecting frog reproduction. Nonetheless, whether this is the case over the long-term is difficult to address in the absence of long-term water quality data.

Similarly, the survival of Southern Brown Tree Frogs declines in elevated saline conditions (Chinathamby et al. 2006), with lower numbers of Southern Bullfrogs have been recorded in stormwater ponds with

¹ Rainfall data drawn from Wensleydale (station no. 87119), except for August 2014, when data were not collected at this station, and data drawn instead from Aireys Inlet (no. 90180).

elevated salinity (Hamer et al. 2012). High saline levels may also have a negative impact on adult frog populations, making them more prone to desiccation. Moderately high salinity/electrical conductivity levels were recorded at both the Swamp (0.02–3.93 ms/cm) and Estuary (4.04–10.90 ms/cm), which may further reduce the potential for frogs to successfully reproduce in these areas. As such, the combination of these factors could act to further reduce the likelihood of successful reproduction of amphibians at sites within the Anglesea swamp and estuary.

Table 15 Number of survey sites in the Anglesea Swamp and Anglesea Estuary at which frogs were recorded during spring surveys of the Anglesea MAP, 2014–20.

Area	Common name	Species	2014	2015	2016	2017	2019	2020
Anglesea Swamp	Southern Tree Frog	<i>Litoria ewingii</i>	0	0	2	1	0	0
	Southern Bullfrog	<i>Limnodynastes dumerilii</i>	0	0	2	1	0	0
	Common Froglet	<i>Crinia signifera</i>	0	0	3	1	0	1
		Any species	0	0	4	1	0	1
Anglesea Estuary	Southern Tree Frog	<i>Litoria ewingii</i>	NA	0	NA	0	0	0
	Southern Bullfrog	<i>Limnodynastes dumerilii</i>	NA	1	NA	1	0	2
	Common Froglet	<i>Crinia signifera</i>	NA	2	NA	0	0	0
		Any species	NA	3	NA	1	0	2

4.3 Aquatic Ecology

The macroinvertebrate monitoring results were relatively consistent with previous years, although almost all indices showed a marginal reduction compared with the 2019 results. The exception was for EPT at sites BCT1 and SC1, which were higher, and the number of taxa at SC1 (identical to 2019). The low abundance and diversity of macroinvertebrates detected, and poor performance against SEPP (W) objectives could be attributed to a few different factors. In particular, the low water levels and limited surface water at BCT1 and W2/3 resulted in a corresponding scarcity of habitat to sample. The site SC1 showed the best result in terms of macroinvertebrate community and also the largest volume of water and habitat available, as expected. A combination of low level of surface water and poor habitat is likely to affect the results by both limiting the area/habitat available during sampling and reducing the likelihood that the full suite of macroinvertebrates can persist within those sites. Moreover, consecutive years at a low water level and reduced habitat have now been recorded at BCT1 and W2/3, likely worsening these effects. Whereas, site SC1 habitat suitability has remained relatively consistent over the past few years, and relatively similar in terms of the macroinvertebrate community. Overall, it appears that the macroinvertebrate community within SC1 has been fairly stable through time, whereas the community at sites BCT1 and W2/3 are showing diminishing signs. The additional sampling (i.e. a greater number of sites sampled) that is undertaken triennially as per the MAP (Victorian Government, 2014) is due to be completed in 2021. This more comprehensive sampling will provide an improved understanding of long term macroinvertebrate community changes.

The Southern Pygmy Perch population at site SC1 has shown a sizeable increase in catch between 2019 and 2020 which may indicate a substantial increase in population size to levels not seen since 2015. The increase appears driven by strong recent recruitment resulting in a dominant cohort of juvenile and

young of year fish. Conversely, this was the third year in a row that no Southern Pygmy Perch have been detected at BCT1. This result is alarming as it may indicate the extirpation of the species population in the local area. However, previous reports for this species have noted that populations can reappear after several years of no recruitment (GHD 2013–2015). This suggests that the site surveyed during this project is possibly not the Breakfast Creek 'source population' and is a site where extirpation and subsequent re-colonisation from a nearby source population have occurred previously. If so, more consistent and representative monitoring results are likely to be obtained from an additional or alternative site in the Breakfast Creek catchment. Given the population of Southern Pygmy Perch in the Anglesea catchment is genetically distinct when compared to nearby catchments (Cesar 2012), it is important to maintain the population within both Salt Creek and Breakfast creek. The persistence of suitable habitat within drought refuge pools is expected to be the key to ensuring the persistence of source populations. Identification and monitoring of such sites should therefore form an important component of the monitoring program.

Otway Bush Yabby populations within both SC1 and BCT1 were the highlight of the 2020 survey, with more than triple the number detected in 2020 compared with 2019. They were abundant in both the deeper and more stable SC1 as well as in the shallow and poorly connected pools of BCT1, meaning that with this species able to complete its life cycle in both permanent and more intermittent habitats, with a large proportion of small individuals detected at both sites (indicative of good recruitment). This species was first detected in Salt Creek in 2007 (Schultz 2007) but was likely misidentified as Common Yabby *Cherax destructor* or unidentified Parastacidae (from the macroinvertebrate samples) until 2017, as all Parastacidae recorded since 2017 have been Otway Bush Yabbies. Since 2017 the Otway Bush Yabby population appears to be increasing further, with 2020 being the highest catch rate recorded, and more than triple that recorded in the previous year. Based on both the abundance and broad size range detected, it appears that a healthy population occurs at sites BCT1 and SC1. The apparent boom in the recruitment of Otway Bush Yabby may also be a sign of increasing intermittency and a reduction in the quality of habitat for fish (including eels) within the borefields.

Recommendations regarding the aquatic monitoring component were proposed after the 2018 monitoring event (Ecology Australia 2019). These recommendations remain current and are reproduced and expanded upon following the 2020 event below:

- Due to the limited presence of surface water, it may be beneficial to reduce the number of macroinvertebrate samples per site from three down to two, to avoid oversampling which likely results in poorer results per sample. As the new SEPP (W) indices for macroinvertebrates are based on single samples, there is greater importance in collecting higher quality individual samples. The trade-off of this approach in terms of reduced replication and reduced data compatibility also requires consideration. It should be noted that to overcome the issue of low surface water availability in 2020, the site BCT1 was slightly expanded compared with the site boundary in 2019 (when only two samples were successfully taken). The suitability of this change being made permanent would best be considered as part of a review of the MAP.
- Given the recent failures to detect Southern Pygmy Perch at BCT1, it would be beneficial to survey additional/alternative locations on Breakfast Creek to establish if the population of Southern Pygmy Perch persists. In addition, it would be beneficial to reassess the catchment as a whole for additional populations. This has not been done since 2012, and would ideally

focus on historic records from Anglesea River and associated wetlands and Breakfast Creek, identification of refuge pools in the Breakfast Creek catchment, and investigation of known refuge pools throughout Salt Creek and Anglesea River (as identified in GHD 2010). As a genetically distinct population in an isolated catchment, it is of concern that the species may have retracted to a single remnant population. This results in a high level of vulnerability for this genetic lineage. This assessment can be undertaken at any time, but would ideally be undertaken in late summer/autumn in terms of maximising capture rates.

- The 2019 and 2020 surveys have now both included Otway Bush Yabby as a target species and the population has shown signs of stability and growth in the area. Including investigations into the extent of the population throughout the study area should be included in the triennial macroinvertebrate survey. This requires no modification to the methods other than collecting data from the specimens collected. This additional effort could further be expanded by including this species in an expanded Southern Pygmy Perch catchment assessment, as the survey methodology would be similar and cost-effective.
 - In addition, we recommend that occipital carapace length (OCL) for up to 30 individuals per site per method to the nearest mm be recorded for Otway Bush Yabby for all future monitoring targeting this species. This data may then be used and present in a similar way to the lengths present for the Southern Pygmy Perch (i.e. length-frequency histograms) and OCL data will allow for a greater understanding of the size classes present within the borefields for this species.

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Appendix 1 Anglesea Borefield, terrestrial ecology, Monitoring and Assessment Program,
Anglesea Swamp, native plant species and Functional Groups (native plant species
only) spring 2020

Status	Scientific name	Common name	Functional group	AS2	AS3	AS4	ASP7_2014	AS1_2014	AGP2_2014
	<i>Banksia marginata</i>	Silver Banksia	Tdr			✓			
	¹ <i>Machaerina arthropphylla</i>	Fine Twig-sedge	Se			✓	✓	✓	✓
	<i>Machaerina juncea</i>	Bare Twig-sedge	Tda				✓	✓	
	<i>Machaerina tetragona</i>	Square Twig-sedge	Se	✓	✓	✓			
	<i>Cassytha glabella</i>	Slender Dodder-laurel	Tdr		✓	✓	✓	✓	
	<i>Cycnogeton procerum</i> sp. aff.	Common Water-ribbons	Se	✓		✓	✓	✓	✓
	<i>Eleocharis sphacelata</i>	Tall Spike-sedge	Se					✓	
	<i>Empodisma minus</i>	Spreading Rope-rush	ATe		✓	✓	✓	✓	✓
	<i>Epacris obtusifolia</i>	Blunt leaf-Heath	ATw		✓	✓	✓		
r	<i>Eucalyptus falciformis</i>	Western Peppermint	Tdr	✓					
	<i>Gahnia radula</i>	Thatch Saw-sedge	Tdr	✓					
	<i>Gahnia sieberiana</i>	Red-fruit Saw-sedge	ATe	✓		✓	✓		✓
	<i>Gleichenia dicarpa</i>	Pouched Coral-fern	ATe		✓	✓	✓	✓	
	<i>Gleichenia microphylla</i>	Scrambling Coral-fern	ATe			✓			
	<i>Juncus procerus</i>	Tall Rush	ATe	✓					✓
	<i>Lepidosperma longitudinale</i>	Pithy Sword-sedge	ATe			✓	✓		✓
	<i>Leptospermum continentale</i>	Prickly Tea-tree	Tdr		✓	✓	✓	✓	
	<i>Leptospermum lanigerum</i>	Woolly Tea-tree	ATw				✓		
	<i>Leptospermum scoparium</i>	Manuka	Tda	✓				✓	✓
	<i>Melaleuca squarrosa</i>	Scented Paperbark	ATw	✓	✓	✓	✓	✓	✓
	<i>Opercularia varia</i>	Variable Stinkweed	Tdr	✓					
	<i>Platylobium obtusangulum</i>	Common Flat-pea	Tdr	✓					

Status	Scientific name	Common name	Functional group	AS2	AS3	AS4	ASP7_2014	AS1_2014	AGP2_2014
	<i>Pteridium esculentum</i>	Bracken	Tdr	✓				✓	
	<i>Rytidosporum procumbens</i>	White Marianth	Tdr	✓					
	<i>Schoenus brevifolius</i>	Zig-zag Bog-sedge	ATe	✓	✓	✓	✓	✓	
	<i>Sprengalia incarnata</i>	Pink Swamp-heath	ATw		✓	✓	✓		
	<i>Xyris operculata</i>	Tall Yellow-eye	ATe		✓				

¹ *Machaerina* is synonymous with *Baumea* recorded in previous surveys.

Appendix 2 Anglesea Borefield, terrestrial ecology, Monitoring and Assessment Program, Anglesea Estuary, plant species and Functional Groups (native plant species only) spring 2020

Key:

= Victorian species not indigenous to the region, location or local area

* = Species not native to Victoria

Status	Scientific name	Common name	Functional group	LAR1	LAR2	LAR3	LAR4
#	<i>Acacia longifolia</i> subsp. <i>longifolia</i>	Sallow Wattle	NA			✓	
#	<i>Acacia longifolia</i> subsp. <i>sophorae</i>	Coast Wattle	NA	✓			
	<i>Acacia verticillata</i>	Prickly Moses	Tdr			✓	
*	<i>Aira elegantissima</i>	Delicate Hair-grass	NA			✓	
*	<i>Anthoxanthum odoratum</i>	Sweet Vernal-grass	NA			✓	
	<i>Cassytha melantha</i>	Coarse Dodder-laurel	Tdr				✓
	<i>Cycnogeton procerum</i> sp. aff.	Common Water-ribbons	Se	✓	✓		✓
	<i>Eucalyptus ovata</i> var. <i>ovata</i>	Swamp Gum	Tda	✓		✓	
	<i>Ficinia nodosa</i>	Knobby Club-sedge	Tdr			✓	
	<i>Gahnia sieberiana</i>	Red-fruit Saw-sedge	ATe	✓			
	<i>Goodenia ovata</i>	Hop Goodenia	Tdr	✓	✓	✓	✓
	<i>Goodenia radicans</i>	Shiny Swamp-mat	ARp			✓	
*	<i>Holcus lanatus</i>	Yorkshire Fog	NA	✓		✓	
*	<i>Hypochaeris radicata</i>	Cat's Ears	NA			✓	
	<i>Juncus kraussii</i> ssp. <i>australiensis</i>	Sea Rush	Se	✓	✓	✓	✓
	<i>Lachnagrostis filiformis</i>	Common Blown-grass	Tdr		✓	✓	
	<i>Leptinella longipes</i>	Coast Cotula	ARp		✓	✓	✓
	<i>Leptosperum scoparium</i>	Manuka	Tda	✓	✓	✓	✓
	<i>Lobelia anceps</i>	Angled Lobelia	ATe	✓	✓	✓	✓
*	<i>Lotus</i> sp.	Lotus	NA			✓	
	<i>Myoporum insulare</i>	Common Boobialla	Tda		✓	✓	
	<i>Phragmites australis</i>	Common Reed	ARp	✓	✓	✓	
*	<i>Plantago coronopus</i>	Buck's-horn Plantain	NA		✓	✓	
	<i>Poa poiformis</i> var. <i>poiformis</i>	Coast Tussock-grass	Tdr		✓	✓	✓
	¹ <i>Goodenia radicans</i>	Shiny Swamp-mat	ARp	✓	✓		✓

Status	Scientific name	Common name	Functional group	LAR1	LAR2	LAR3	LAR4
	<i>Senecio glomeratus</i>	Annual Fireweed	Tdr		✓		
*	<i>Sonchus oleraceus</i>	Sow Thistle	NA			✓	
*	<i>Vulpia bromoides</i>	Squirrel-tail Fescue	NA			✓	

¹*Goodenia radicans* is synonymous with *Selliera radicans* recorded in previous surveys

Appendix 3 Results by sample of macroinvertebrate sampling in 2020. (E1 = Edge sample 1, E2 = Edge sample 2 and E3 = Edge sample 3)

Taxa	W2/3				BCT1				SC1				Total
	E1	E2	E3	Total	E1	E2	E3	Total	E1	E2	E3	Total	
Acarina				0				0	1			1	1
Amphipoda				0				0	4			4	4
Ceratopogonidae	1			1				0				0	1
Chironominae			7	7			2	2	3	1	28	32	41
Culicidae	19			19			4	4			1	1	24
Curculionidae				0				0			1	1	1
Dytiscidae	4		4	8	8		1	9	3		36	39	56
Gripopterygidae				0	1			1				0	1
Hydrochidae				0				0		1	1	2	2
Hydrophilidae	1			1				0			1	1	2
Koonungidae				0				0			4	4	4
Leptoceridae (<i>Lectrides</i>)				0				0			1	1	1
Leptoceridae (<i>Leptorussa</i>)				0			6	6				0	6
Leptoceridae (<i>Triplectides</i>)				0	2	1	6	9			1	1	10
Leptophlebiidae				0				0	1		2	3	3
Leptophlebiidae (<i>Ulmerophlebia</i>)				0	1			1	1	4	2	7	8
Oligochaeta				0			1	1				0	1
Paramelitidae				0				0	4	14	24	42	42
Polycentropodidae (<i>Plectrocnemia</i>)				0	2			2	1			1	3
Scirtidae	10	6	27	43				0		1	1	2	45
Tanypodinae				0				0	3			3	3
Tipulidae				0				0	1			1	1
Veliidae				0				0	18		9	27	27
Total	35	6	38	79	14	1	20	35	40	21	112	173	287



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Anglesea Borefield Ecological Monitoring and Assessment Program 2019



Prepared for: Barwon Water

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- Wildlife and Small Institutions Animal Ethics Committee (WSIAEC) projects 06.19 and 07.19;
- Fisheries Research Permit 1142;
- *Wildlife Act 1975, Flora and Fauna Guarantee Act 1988, and National Parks Act 1975* Research Permit 10007806; and
- Scientific Procedures Fieldwork Licence 20097.

Summary

Introduction

Under the *Bulk Entitlement (Anglesea Groundwater) 2009* (BE) (Victorian Government 2009), Barwon Water is permitted to extract water to supplement the water supply to Geelong and surrounding areas when required. The BE requires data to be collected to monitor the impacts of water drawdown under a Monitoring and Assessment Program (MAP) established in 2009. The MAP includes groundwater and surface water monitoring, acid sulfate investigations, land level surveying and aquatic and terrestrial ecological monitoring.

The MAP was last revised and updated in 2014 (Victorian Government 2014). The MAP currently requires monitoring of aquatic components (macroinvertebrates and fish) to be undertaken annually, and monitoring of terrestrial components (vegetation and frogs) to be undertaken biennially in the absence of groundwater pumping and annually during periods of groundwater extraction. With the exception of the second frog survey (December 2019), all sampling conducted for this report was completed prior to the operation of the borefield. Barwon Water made the decision to operate the Anglesea borefield to supplement urban water supplies in November 2019.

Ecology Australia was commissioned to undertake both the aquatic and terrestrial ecological monitoring in 2019 and has undertaken the terrestrial monitoring (vegetation and frogs) since 2009 and the aquatic ecology monitoring since 2017.

Methods

Vegetation monitoring was undertaken along six permanent transects in the Anglesea Swamp and four permanent transects in the Anglesea Estuary. The data collected included:

- Plant species lists;
- Ecological Vegetation Class (EVC);
- Plant Functional Group;
- Bare ground cover; and
- Water depth (in the swamp only).

Frog survey data was collected at eight sites in the Anglesea Swamp and four sites in the Anglesea Estuary and included:

- Species richness;
- Abundance;
- Water quality; and
- Habitat attributes.

Aquatic monitoring consisted of targeted survey for Southern Pygmy Perch at two sites, and macroinvertebrate sampling at three sites. Since the detection of Otway Bush Yabby *Geocharax tasmanicus* (formerly *G. gracilis*) in 2017, this species has been monitored opportunistically via the existing monitoring regime for fish and macroinvertebrates. Fish and macroinvertebrate monitoring included:

- Taxonomic diversity (macroinvertebrates);
- Abundance;
- Biometrics (fish);
- Water quality; and
- Habitat attributes.

Findings

Vegetation

Ecological Vegetation Classes, plant Functional Groups, plant species numbers and frequency remain largely unchanged in the Anglesea Swamp and Anglesea Estuary.

Standing water was again recorded at all sites in the swamp and algal mats were present at three sites and at one site in the estuary.

Bare ground cover has fluctuated in the Anglesea Swamp but is considered to be within the normal limits of seasonal variation.

Rainfall records indicate average annual rainfall has been highly variable since 2014.

Vehicle tracks were observed in the swamp at site ASP7_2014 and it is recommended that vehicle access be prevented in future to reduce substrate disturbance and vegetation damage.

Frogs

Frogs were not recorded at any of the Anglesea Swamp survey sites during either survey, although Southern Brown Tree Frogs *Litoria ewingii* and Southern Bullfrogs *Limnodynastes dumerilii* were heard calling at least 100 m away from several sites during the first survey. A single Southern Bullfrog was observed near one of the Anglesea Estuary sites during the second survey; otherwise no frogs were heard calling or observed at the estuary survey sites. However, frogs were heard calling at least 100 m from nine of the twelve survey sites, suggesting that they do occur in the broader area. The 2019 results are consistent with previous surveys, where low numbers and diversity of frogs have been recorded across the survey sites.

Southern Pygmy Perch

Southern Pygmy Perch were detected from one of the two monitoring sites, SC1, which is consistent with the results of the most recent survey. No recruitment was detected at site SC1, a spring sampling result that has not occurred previously. With two successive surveys failing to detect Southern Pygmy Perch at BCT1, it would be advisable to determine if there is a source population elsewhere in the Breakfast Creek catchment.

Macroinvertebrates

Macroinvertebrate community indices comparison against State Environment Protection Policy (SEPP)(Waters) objectives was consistent with previous years, with low abundance and diversity, but occasional samples meeting SIGNAL2 score objectives.

Otway Bush Yabby was again detected at BCT1 and SC1, and there was evidence of recent recruitment. This species has been consistently detected since 2017, and based on earlier reports, there is evidence of the species presence within the study area prior to 2017.

1 Introduction

Barwon Water is permitted to extract groundwater from the Anglesea Borefield, under the *Bulk Entitlement (Anglesea Groundwater) 2009* (BE), to supplement the water supply to Geelong and surrounding areas when required. Groundwater pumping under the BE is permitted as long as it does not adversely affect environmental values and ground water dependent ecosystems in the Jan Juc Groundwater Management Area.

The BE requires data to be collected to monitor the impacts of water drawdown. At the commencement of the BE a Monitoring and Assessment Program (MAP) was developed. The MAP includes groundwater and surface water monitoring, acid sulfate investigations, land-level surveying and aquatic and terrestrial ecological monitoring. The MAP has been revised and updated once, in September 2014.

Ecology Australia has undertaken the terrestrial (vegetation and frogs) monitoring component of the MAP since 2009 and the aquatic component (fish and macroinvertebrates) since 2017 (Ecology Australia 2009–2017).

The current MAP requires aquatic ecological monitoring to be undertaken annually, and terrestrial ecological monitoring to be undertaken biennially in the absence of ground water pumping and annually during periods of ground water extraction. With the exception of the second frog survey (undertaken in December 2019), all sampling conducted for this report was completed prior to the operation of the borefield. Barwon Water made the decision to operate the Anglesea borefield to supplement urban water supplies in November 2019. The terrestrial ecological monitoring was last undertaken in 2017 and was due again in 2019.

The 2019 ecological monitoring includes the Aquatic Ecology and Terrestrial Ecology components as detailed below.

1.1 Aquatic Ecology

The Aquatic Ecological monitoring component included spring monitoring of macroinvertebrates at three sites:

- Breakfast Creek tributary (BCT1);
- Salt Creek (SC1); and
- Lower Anglesea River wetland (Wetland 3).

Additionally, this component included spring sampling of Southern Pygmy Perch *Nannoperca australis* at two sites:

- Breakfast Creek tributary (BCT1); and
- Salt Creek (SC1).

1.2 Terrestrial Ecology

The Terrestrial Ecological monitoring component included spring monitoring of vegetation along established transects at six sites and frog monitoring at eight sites in the Anglesea Swamp (Figure 1):

- AS1_2014 (vegetation and frog monitoring);
- AS2 (vegetation and frog monitoring);

- AS3 (vegetation and frog monitoring);
- AS4 (vegetation and frog monitoring);
- AS5 (frog monitoring only);
- AS6 (frog monitoring only);
- ASP7_2014 (vegetation and frog monitoring); and
- AGP2_2014 (vegetation and frog monitoring).

Additionally, spring monitoring of vegetation along was undertaken at established transects at four sites and frog monitoring was undertaken at the same sites in the Anglesea Estuary (Figure 1):

- LAR1;
- LAR2;
- LAR3; and
- LAR4.

Vegetation data collection included: floristic species lists, Ecological Vegetation Classes (EVCs), plant Functional Groups, and other structural attributes (water depth, bare ground and algal mats).

The frog monitoring data collection included: species richness, abundance, water quality, and habitat attributes.

This report presents the monitoring methods and results, along with a discussion including a comparison of the 2019 data with annual data collected since the MAP review and update in 2014.



Figure 1 Anglesea Borefield ecological Monitoring and Assessment Program survey sites, 2019.

2 Methods

The aquatic and terrestrial ecology monitoring methods that are provided here follow the revised MAP requirements and remain unchanged since the last round of monitoring conducted in 2017 (Ecology Australia 2017). They are repeated in this report for ease of reference.

2.1 Vegetation

Field work was carried out in the last week of October 2019. Vegetation monitoring was conducted at the following sites in the Anglesea Swamp: AS1_2014, AS2, AS3, AS4, ASP7_2014 and, AGP2_2014 and the following sites in the Anglesea Estuary: LAR1, LAR2, LAR3, and LAR4.

2.1.1 Floristic composition

At each of the sites, plant species and Ecological Vegetation Classes (EVCs) following the Department of Environment, Land, Water and Planning (DELWP) benchmarks (DELWP 2019a) were recorded in sequential 1 m² quadrats located along established 100 m transects. The start and end of all transects are marked by steel pickets. The quadrats are located every second meter along the left hand side of the transect looking from start to end, with the first quadrat placed at 1–2 m, the second quadrat placed at 3–4 m and so on to 99–100 m.

There are 50 quadrats along each transect in the swamp, 15 quadrats along LAR2, LAR3 and LAR4 transects and 7 quadrats along LAR1 in the estuary.

Field staff walk the right hand side of the transect to avoid trampling vegetation within the quadrats.

Plant species were placed into respective plant Functional Groups (FGs) (see Table 1). The FGs and composition of EVCs were analysed to assess hydroecology (Section 2.1.2) and structure (Section 2.1.3).

2.1.2 Hydroecology

The FGs and EVCs were used to assess the degree of groundwater dependent vegetation across the swamp and estuary and the sensitivity of sites to groundwater drawdown.

FGs (Table 1) are based on the hydroecology (known or likely water requirements) of plant species, modified from Cassanova (2011) and Doeg et.al. (2012) as detailed in Ecology Australia (2013b).

FG data is presented in two forms for each of the sites:

- Frequency and FG of the three most dominant species along the transect; and
- Frequency of each broad FG along the transect.

2.1.3 Structural attributes

Vegetation structure was documented through the recorded EVCs, dominant plant species and photo points. Photo points are located at 0 m, 25 m, 50 m, and 75 m along each transect in the swamp and at the start of each transect in the estuary. Photos were taken looking toward the end of the transect.

2.1.4 Other attributes

Other transect attributes recorded were water depth (in the swamp only) and percentage cover of bare ground, rounded to the nearest 5%.

Water depth is a snap shot in time (one day of the year) and will vary considerably over time depending on rainfall. Hydroperiod is a fundamental driver of wetland condition (e.g. Foti et al. 2012).

Bare ground provides space for plant recruitment. This can provide an indication of potential change at a site, for example — are the extant FGs recruiting, or are conditions favouring the recruitment of drier or wetter groups?

In 2016, large amounts of ‘algal mat’ (consisting of filamentous algae) were observed in quadrats for the first time since the revised MAP monitoring commenced in 2014. The presence of an algal mat was noted again in 2019, with presence being recorded for each quadrat.

2.1.5 Wetland boundaries

Wetland boundaries in the Anglesea Swamp were confirmed as far as practicable by mapping the interface between Swamp Scrub and Aquatic Sedgeland using aerial imagery and ground-truthing. This mapping should detect significant boundary shifts in response to any longer term hydrological change.

Table 1 Anglesea Borefield, ecological Monitoring and Assessment Program, Plant Functional Groups (modified from Cassanova (2011) and Doeg et.al. (2012))

Functional group code	Definition	Example species	Broad category
Tdr	<i>Terrestrial dry</i> . This species group does not require flooding and will persist in damper parts of the landscape because of localised high rainfall. Species in this group can invade or persist in riparian zones and the edges of wetlands, but are essentially terrestrial.	Messmate, Brown Stringybark, Prickly Moses, Silver Banksia	Dry
Tda	<i>Terrestrial damp</i> . These species germinate and establish on saturated or damp ground, but cannot tolerate flooding in the vegetative state. They require the soil profile to remain damp for at least several months.	Swamp Gum, Variable Sword-sedge, Manuka , Slender Bog-sedge	
ATI	<i>Amphibious fluctuation tolerator - low-growing</i> . This species group can germinate either on saturated soil or under water and grow submerged, as long as they are exposed to air by the time they start to flower and set seed. They require or tolerate shallow flooding for approximately 3 months.	Austral Brookline, Swamp Club-sedge, Spotted Knotweed	Amphibious
ATe	<i>Amphibious fluctuation tolerator-emergent</i> . This species group consists of emergent monocots and dicots that survive in saturated soil or shallow water but require most of their photosynthetic parts to remain above the water (emergent). They tolerate fluctuations in the depth of water, as well as water presence. They need water or soil moisture to be present for 8-12 months of the year.	Tall Sedge, Red Fruit Saw-sedge, Pouched Coral-fern, Scrambling Coral-fern	
ATw	<i>Amphibious fluctuation tolerator- woody</i> . This species group consists of woody perennial species that may hold their fruits (and seeds) in the canopy and require water to be present in the root zone all year round, but will germinate in shallow water or on a drying substrate.	Woolly Tea-tree, Scented Paperbark	
ARp	<i>Amphibious fluctuation responder- plastic</i> . This species group occupies a similar zone to the ATI group, except that they have a morphological response to water level changes such as rapid shoot elongation or a change in leaf form. They can persist on damp and drying soil because of their morphological flexibility but can flower even if the site does not dry out. They occupy a slightly deeper/wet-for-longer site than the ATI group.	Creeping Cotula, Monkey Flower, River Buttercup	
Se	<i>Perennial-emergent</i> . This category refers to monocotyledonous species that require permanent water in the root zone, but remain emergent. They occur where water levels do not fluctuate or fluctuate with relatively little drawdown in the dry part of the year.	Cumbungi, Sea Rush, Southern Water-ribbons	Aquatic

2.2 Frogs

Zoologists undertook two repeat surveys for frogs at 12 sites, on 29–30 October (before operation of the borefield) and 9–10 December 2019 (after operation of the borefield):

- AS1_2014, AS2, AS3, AS4, AS5, AS6, ASP7_2014 and AGP2_2014 in the Anglesea Swamp; and
- LAR1, LAR2, LAR3 and LAR4 in the Anglesea Estuary (Figure 1).

Survey sites comprise the ten sites required by the MAP, as well as two additional sites (AS5 and AS6), which are surveyed in the event that very low frog activity is observed in the Anglesea Swamp.

2.2.1 Habitat assessment and water quality

To supplement the habitat data collected as part of vegetation monitoring, the following variables were recorded in relation to frog habitat:

- Wetland permanence (i.e. ephemeral, semi-permanent or permanent);
- Water quality parameters:
 - Temperature (° C);
 - pH;
 - Electrical Conductivity (EC);
 - Dissolved Oxygen (DO); and
 - Turbidity (NTU).
- A general habitat description, including levels of cover of fringing, emergent, submergent and floating vegetation where present.

Photos were also taken showing characteristic frog habitat at each survey site.

2.2.2 Frog surveys

Zoologists used both diurnal and nocturnal visual encounter surveys to detect frogs at the survey sites. Nocturnal surveys also included call playback and spotlighting. Weather conditions at the time of survey were recorded using a Kestrel weather meter. However, high rainfall, aseasonally low Spring temperatures, and high winds, resulted in the final frog sampling event being delayed until the site could be safely accessed and weather conditions were suitable in early Summer 2019.

Visual encounter surveys

Visual and aural encounter surveys were undertaken at each site during the diurnal habitat assessment and at the beginning of each nocturnal survey. Surveys comprised two zoologists listening for a period of approximately five minutes for the distinctive calls of male frogs. The species heard, and estimation of the number of frogs calling for each species, were recorded. In addition, zoologists looked for frogs at each site, by traversing the sites and scanning vegetation and the water surface for the presence of frogs. Visual encounter during nocturnal surveys was aided by the use of headtorches and/or hand-held spotlights, to look for the distinctive eye-shine of frogs.

Nocturnal call playback

Call playback was used after the nocturnal aural survey, to elicit calling by male frogs that were not calling independently onsite. This involved the broadcast of pre-recorded calls of each species through a speaker, followed by a period of quiet listening. Frog calls broadcast during call playback, based on previous records included:

- Southern Brown Tree Frog *Litoria ewingii*;
- Southern Bullfrog *Limnodynastes dumerilii*;
- Spotted Marsh Frog *Limnodynastes tasmaniensis*;
- Striped Marsh Frog *Limnodynastes peronii*;
- Common Spadefoot Toad *Neobatrachus sudellae*;
- Victorian Smooth Froglet *Geocrinia victoriana*; and
- Common Froglet *Crinia signifera*.

Call response data were used to estimate frog species richness and abundance within each site across the Anglesea Catchment and Estuary.

2.3 Aquatic ecology

2.3.1 Macroinvertebrate surveys

Macroinvertebrate surveys were undertaken at three sites on 29–30 October 2019. Site BCT1 was again relocated downstream to stream gauge SV3, consistent with previous years (Ecology Australia 2019) however for consistency it will be referred to as BCT1. Wetland 2 and Wetland 3 were combined into a single site, as they act as a single waterbody due to connectivity between the two sites, and as there was insufficient water in either one to collect three samples, but sufficient water once the two sites were combined.

As per the established methods (GHD 2016), triplicate edge samples were collected at each site where sufficient surface water was present following the methods outlined in the Victorian Rapid Bioassessment (RBA) Methodology for Rivers and Streams (EPA 2003). A 0.25 mm mesh net with a 30 cm x 30 cm opening was used to collect each sample. Edge ('sweep') samples were collected from water bodies with little to no flow. The sampling objective was to subsample all types of habitats present, which can include overhanging vegetation, coarse woody debris, backwaters, bare edges, leaf packs and macrophytes. Each sample consisted of 10 m of habitat, which was not necessarily contiguous. The water and habitat was agitated to dislodge macroinvertebrates and suspend them within the water column. Additional macroinvertebrates which were observed but not collected (e.g. fast moving) were noted on the sample label.

Samples were live-sorted ('picked') following the standard RBA procedures and preserved in 70% ethanol. In summary, the procedures entail:

- Picking for 30 minutes from a white tray, aiming to collect 200 animals from as many different taxa as possible;
- If less than 200 animals are collected within 30 minutes then picking continues for an additional 10 minutes;

- If 200 animals are collected within 40 minutes and no new taxa are detected, then picking ceases; otherwise picking continues for an additional 10 minutes. This continues until a maximum of 60 minutes of picking has been completed; and
- Avoidance of favouring large and abundant taxa over smaller, more cryptic taxa, by picking a maximum of approximately 30 of each taxa, with the exception of animals which may superficially appear to be the same but typically require microscopic examination to identify the additional taxa (e.g. taxa which are to be identified to a lower taxonomic resolution).

At each site, RBA field sampling and habitat assessment sheets were completed, including in situ water quality measurements using a calibrated U-52 Horiba water quality meter.

Upon detection of Otway Bush Yabby in 2017 it was requested by Mark Dodgshun of Barwon Water that this species be monitored concurrently with the effort that was being employed for fish and macroinvertebrates (Ecology Australia 2018).

Macroinvertebrate identification

Macroinvertebrates were identified and enumerated with a stereo microscope using keys outlined in MDFRC (2013), which provides an update on those outlined in Hawking (2000). The majority of taxa were identified to family level with the following exceptions as per the RBA protocols (EPA 2003):

- Chironomidae are identified to sub-family;
- Oligochaeta and Acarina are not identified below these taxonomic levels;
- Adult and larval beetles are listed separately;
- Taxa excluded from the recommended indices were discarded
- Specimens of the orders Ephemeroptera, Plecoptera, Trichoptera and Odonata were identified to genus level, as per GHD (2015–2017) and Ecology Australia (2018–2019).

2.3.2 Macroinvertebrate data analyses

Macroinvertebrate data were analysed both as individual samples, and on a site basis using the combined data from three samples. Where available, the results were compared against indices objectives outlined in State Environment Protection Policy – Waters (SEPP-W) (Victorian Government Gazette 2018).

The following indices were used to analyse macroinvertebrate data:

- Number of taxa — total number of taxa based on taxonomic resolution levels described above;
- Abundance — total number of individuals collected excluding those that were discarded (e.g. Collembolla, Staphlinidae beetles);

SIGNAL2 score — average SIGNAL score for taxa collected in each sample, based on methods of Chessman (2003).

- Table 2 provides the corresponding water quality categories;

- Number of EPT taxa — number of taxa from the orders of Ephemeroptera, Plecoptera and Trichoptera (EPT), which are considered more sensitive to pollution and disturbance and hence are considered an indicator of ecosystem health;
- Number of EPTO taxa — number of taxa from the orders of Ephemeroptera, Plecoptera, Trichoptera and Odonata (EPTO). This index is used for waterways in 'Mediterranean climate' regions, and aids in interpreting the health of lentic (still water) systems, where the numbers of Plecoptera are diminished while Odonata, which are also relatively sensitive to pollutants and disturbance, are more abundant and diverse (Pinto et al. 2004)

Table 2 SIGNAL score classifications (Chessman 1995)

SIGNAL score	Water quality
>7	Excellent
6-7	Clean water
5-6	Mild pollution
4-5	Moderate pollution
<4	Severe pollution

2.3.3 Fish surveys

Surveys targeting Southern Pygmy Perch *Nannoperca australis* were undertaken at two sites; SC1 and BCT1 on 29–30 October 2019. As with the macroinvertebrate surveys, site BCT1 was relocated downstream due to insufficient surface water (see section 3.3.1).

Ten bait traps (mesh size of 2 mm and funnel entrances of 4 cm) with 10 cm yellow glow sticks were set in the afternoon and retrieved the following morning at both sites. This is a modification of the methods used by GHD (2015–2017), where it is believed that five bait traps were set each year during surveys conducted from 2012–2016 (GHD 2013–2017), but is consistent with monitoring in recent years (Ecology Australia 2018–2019). The number of traps was increased to increase the likelihood of collecting 30 Southern Pygmy Perch per site.

The first 30 Southern Pygmy Perch were required to be measured (total length) to the nearest millimetre, and weighed to the nearest 0.1 gram. Subsequent Southern Pygmy Perch were also measured to increase the accuracy of population structure estimates. Additional taxa of interest detected in bait traps or observed at each site were recorded, with a particular focus on threatened crayfish Otway Bush Yabby *Geocharax tasmanicus* (formerly *G. gracilis*).

Instream habitat assessment was undertaken at all sites surveyed. The habitat assessment included notes on existing sources of disturbance, notes and estimates of biological and physical attributes (e.g. wetted instream cover, riparian shading, aquatic vegetation, substrate composition, flow and depth) and in situ water quality measurement. An outline of some of these habitat descriptors is provided below:

- The percentage cover of various forms of instream habitat (based on the proportion of the wetted area that they covered at the time of assessment).
- The shading estimate as per the EPA Rapid Bioassessment method (EPA 2003). This is an estimate based on a plan view as it would appear with the sun directly overhead (i.e. midday).
- The flow status estimate is as per the USEPA field sheets that are incorporated into the latest iteration of the Victorian EPA Rapid Bioassessment field sheets (Version: September 2012). This is an estimate based on the proportion of the channel filled and/or substrate exposed.
- The disturbance rating estimate is based on identification of a number of disturbance sources including levels of bank erosion, riparian vegetation clearance, parallel or adjacent roads, bridges/culverts/fords, rubbish, drain input, water extraction points, stock access, sedimentation, invasive exotic vegetation, barriers to fish passage, channelization and hydrological alterations; together with a severity rating (i.e. high, medium, low) applied to the disturbance sources that were identified at a given site.

Water quality measurements (dissolved oxygen (mg/L), pH, temperature (degrees Celsius), conductivity (mS/cm) and turbidity (NTU)) were made with a calibrated Horiba U-52 water quality meter.

2.4 Conservation status

Threatened species of State and/or National conservation significance were determined by reference to the Victorian Government Advisory Lists (DSE 2009, 2013, DEPI 2014) including listings under the *Victorian Flora and Fauna Guarantee Act 1988* (FFG Act) and the *Commonwealth Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

2.5 Nomenclature and taxonomy

The scientific names, common names and systematic orders of flora and fauna taxa follow the Victorian Biodiversity Atlas (DELWP 2019b). Common names are generally used for fauna in the text.

Where an asterisk (*) precedes a plant name it is used to signify non-indigenous taxa, those species which have been introduced to Victoria or Australia. A hash (#) is used to denote Victorian plant species that are not indigenous to the region or local area.

3 Results

Vegetation and frog monitoring were undertaken at the same sites (with two additional sites for frogs). Findings for each site are presented below followed by site summaries in Section 4.2.3.

The aquatic ecology monitoring was carried out at sites in different locations to the terrestrial monitoring sites and as such the site summaries are presented separately in Sections 4.3–4.7.

3.1 Vegetation

Site summaries displaying the results of the vegetation monitoring area provided in Figures 2, 4, 6, 8, 10, 12, 16, 18, 20 and 22.

3.1.1 Floristic composition

A total of 28 indigenous plant species was recorded across all sites in the Anglesea swamp (Appendix 1), while in the Anglesea estuary a total of 16 indigenous plant species, three exotic plant species and two native Victorian species not indigenous to the location were recorded (Appendix 2).

Native species richness at any one site ranged from 8–16 in the swamp and 8–13 in the estuary (Table 3).

Table 3 Anglesea Borefield ecological Monitoring and Assessment Program, number of native plant species recorded across monitoring sites and Functional Groups, October 2019.

Transect/Site	Total number of native plant species	Number of plant species in a dry Functional Group (Tdr, Tda)	Number of plant species in an Amphibious Functional Group (Ate, ATw, ARp)	Number of plant species in an Aquatic Functional Group (Se)
Anglesea Swamp				
AS2	15	9	4	2
AS3	10	2	7	1
AS4	16	4	9	3
ASP7_2014	15	3	10	2
AS1_2014	12	6	4	2
AGP2_2014	8	1	5	2
Anglesea Estuary				
LAR1	10	3	4	3
LAR2	9	3	4	2
LAR3	13	7	4	2
LAR4	8	3	3	2

No weeds were recorded in 2019 in the swamp and there was little sign of disturbance with the exception of site ASP7_2014 where there was evidence of vehicle access and obvious vegetation and substrate disturbance (Plates 1–2).



Plate 1 Site ASP7_2014, Anglesea Swamp, evidence of vehicle access, October 2019.



Plate 2 Site ASP7_2014, Anglesea Swamp, evidence of vehicle access, October 2019.

The vegetation in the estuary remains relatively healthy. Although non-indigenous plants were recorded in all transects, there were comparatively greater numbers of native species in each transect (Appendix 2), and indigenous plants were recorded more frequently than weeds in all transects (Figures 16, 18, 20 and 22).

3.1.2 Hydroecology

In the Anglesea swamp five FGs were represented (Tda, Tdr, Se, Ate and ATw) (Table 3). No plants from the ATI or ARp FG's were recorded. Plants from five FG's were also recorded in the Anglesea estuary (Tda, Tdr, Se, Ate and ARp) and no plants from the ATI or ATw FGs were recorded (Table 3).

3.1.3 Structural attributes

Three EVCs recorded in the swamp in 2019 were: Swamp Scrub, representing an open to closed shrubland to 4 m high, Aquatic Sedgeland, characterised by a variably dense cover of sedges to 1.3 m, and Heathy Woodland generally bordering the swamp which has a eucalypt canopy over a shrubby understory. The wetland vegetation was dominated by plants in the Amphibious and Aquatic FGs (Figures 2, 4, 6, 8, 10 and 12).

In the estuary two EVCs were recorded: Swampy Riparian Woodland which consisted of a low open eucalypt canopy to 8 m tall with an understory of scattered woody shrubs and small herbs, and Estuarine Wetland consisting of a dense cover of reeds and rushes to 1 m, with scattered tussock grasses and small herbs. The wetland vegetation was dominated by plants in the Amphibious and Aquatic FGs (Figures 16, 18, 20 and 22).

3.1.4 Other attributes

Water was present at all six sites in the swamp and the average depth ranged from 1–22 cm (Figures 2, 4, 6, 8, 10 and 12).

Bare ground was recorded at one site in the swamp (AGP2_2014) in 2019 and included a 5% cover in two quadrats (an average of 0.2%) (Figures 2, 4, 6, 8, 10 and 12). No bare ground was recorded within the estuary transects (Figures 16, 18, 20 and 22).

Algal mat was recorded at three sites in the swamp and the number of quadrats it was recorded in ranged from 1 (ASP7_2014) to 44 (AS1_2014) (Figures 2, 4, 6, 8, 10 and 12). Algal mat was recorded in one quadrat at one site in the estuary (LAR1).

3.1.5 Wetland boundaries

No changes were observed in the wetland boundaries between the Aquatic Sedgeland and the Swamp Scrub, or between these two EVCs and the adjoining Heathy Woodland (Figures 24–25).

3.2 Frogs

3.2.1 Survey conditions

During the first round of frog surveys on 29–30 October 2019, three of the eight Anglesea Swamp monitoring sites had open standing water and three had very shallow pools. By the second survey, four sites in the swamp had very shallow standing water in small pools, with water levels sufficient to

measure water quality only present at two sites. Water levels were similar to those observed in previous years.

The second frog survey was delayed until early December, due to inclement weather, including low temperatures that are outside the prescribed survey methodology for frog detection, in addition to high rainfall and winds, which presented potential safety issues associated with site access. Conditions during both frog surveys were suitable for detecting frogs, with low wind, moderate temperatures, relatively high humidity and rain falling during the second survey (Table 4).

Table 4 Weather conditions during frog surveys, Anglesea revised ecological Monitoring and Assessment Program, 2019.

Variable	Survey 1	Survey 2
Temperature (°C)	10.5–18.7	12–17
Humidity (%)	61.3–88.1	69.4–80.4
Cloud cover (0–8)	0–6	1–8
Moon light (0–4)	0–1	0–4
Wind speed (0–3)	0–1	0–1
Rainfall during survey (0–3)	0	0–2
Rain in past 24 hours (None–heavy)	None	Low

3.2.2 Frog species richness and abundance

Anglesea Swamp

No frogs were detected at long-term survey points during either survey at the Anglesea Swamp. During the first survey, Southern Brown Tree Frogs were heard calling from near two sites, at least 100 m away, and Southern Bullfrogs were heard near four sites (Table 5). Both species were heard calling near AS3, on Harrison Track North. A maximum of five individuals of each species were heard calling near the survey sites.

Anglesea Estuary

No frogs were heard calling at long-term survey points during either survey at the Anglesea Estuary. One Southern Bullfrog was observed beside a walking track near LAR3 during the second survey (Plate 3). Frogs were heard calling at least 100 m from each of the survey sites during the first survey, and at least 100 m from LAR2 and LAR4 during the second survey (Table 5). Larger numbers of frogs, between 12 and 20, were heard calling in the estuary.

Table 5 Anglesea Borefield revised ecological Monitoring and Assessment Program, frog species detected during surveys and estimated abundances, 2019. The number of frogs heard calling at least 100 m from the survey sites are listed in parentheses.

Site	Southern Brown Tree Frog		Southern Bullfrog		Species Richness
	1	2	1	2	
Anglesea Swamp					
AS2	0	0	0 (1)	0	0
AS3	0 (1–5)	0	0 (1–5)	0	0
AS4	0	0	0	0	0
AS5	0	0	0	0	0
ASP7_2014	0	0	0 (1–5)	0	0
AS1_2014	0	0	0 (1)	0	0
AS6	0	0	0	0	0
AGP2_2014	0 (1–5)	0	0	0	0
Anglesea Estuary					
LAR1	0 (1–5)	0	0	0	0
LAR2	0 (6–10)	0	0 (6–10)	0	0
LAR3	0 (1–5)	0	0	1	1
LAR4	0 (6–10)	0	0 (6–10)	0	0



Plate 3 Southern Bullfrog *Limnodynastes dumerilii* observed beside a walking track at the Anglesea Estuary, near LAR3. Photo: Brett Goodman.

3.2.3 Habitat assessment and water quality

Anglesea Swamp

The Anglesea Swamp monitoring sites mostly support dense shrub cover of Scented Paperbark *Melaleuca squarrosa* and Prickly Teatree *Leptospermum continentale*, which opens up into clearings of emergent aquatic vegetation, largely sedges such as Zig-zag Bog-sedge *Schoenus brevifolius*, Square Twig-sedge *Baumea tetragona* and Fine Twig-sedge *B. arthrophylla*. Swards of dead and live sedges occasionally form thick mats across the site. Fringing vegetation sometimes includes shorter Pink Swamp-heath *Sprengelia incarnata* or Pouched Coral-fern *Gleichenia dicarpa*. Where monitoring sites support standing water, Southern Water-ribbons *Cyanogeton alcockiae* and filamentous algae may be present as submergent and floating vegetation. Some sites also include small patches of bare ground and low cover of woody debris, especially at the interface between emergent and fringing vegetation.

All monitoring sites are considered intermittent except for AS3 (semi-permanent) and AS4 (semi-permanent to permanent). Five sites had sufficient standing water to allow at least some water quality parameters to be measured during the first survey, declining to two sites by the second survey. AS4, AS5 and AS6 had no standing water in either survey and water quality could not be measured. Most sites were acidic (pH of 2.56–3.83) and electric conductivity was moderate, ranging from 801 to 4,540 $\mu\text{S}/\text{cm}$, with all but one measurement above 1,000 $\mu\text{S}/\text{cm}$. Water temperatures were relatively high, with all but two measurements above 15 °C (range: 11.7–26.7 °C). Turbidity and dissolved oxygen could not be measured at some sites due to low water levels. Where measurements were possible, dissolved oxygen levels were variable (range: 1.25–7.5 mg/L) and turbidity was relatively low, with all but one reading below 11 NTU (range: 2–131 NTU).

Anglesea Estuary

The Anglesea Estuary is relatively deep, with slow-moving water. Apart from filamentous algae, cover of aquatic vegetation was generally low, particularly cover of floating and submergent vegetation. Common Reed *Phragmites australis* provides sparse emergent vegetation at most sites. Fringing vegetation occurs at higher levels of cover, dominated by grasses, sedges, rushes and herbs including Coast Tussock-grass, *Poa poiformis* var. *poiformis*, Common Blown-grass *Lachnagrostis filiformis*, Sea Rush *Juncus kraussii* ssp. *australiensis* and Shiny Swamp-mat *Selliera radicans*. LAR1 also supports Narrow-leaf Cumbungi *Typha domingensis* and Southern Water-ribbons. Scattered shrubs of Hop Goodenia *Goodenia ovata* and Manuka *Leptospermum scoparium* and stands of Swamp Gum *Eucalyptus ovata* var. *ovata* were recorded near the water's edge.

All estuary monitoring sites are considered permanent, with stream widths ranging from 2–3 m to approximately 9 m wide, and up to 2 m deep. Water quality could be measured at all sites, and values were consistent between sites within surveys, compared to measurements taken in the Anglesea Swamp. All sites had very low pH (3.32–3.94), and water temperature was generally around 20 °C, apart from cooler readings at LAR1 in the first survey (15.2 °C). Electrical conductivity readings were moderately high, particularly in the second survey, with slightly lower recordings obtained at LAR1, further upstream. Conductivity jumped from a mean of 8,328 $\mu\text{S}/\text{cm}$ in the first survey, to 14,275 $\mu\text{S}/\text{cm}$ in the second survey. Turbidity was low (0–11 NTU) and dissolved oxygen concentrations varied from 4.82 to 9.54 mg/L.

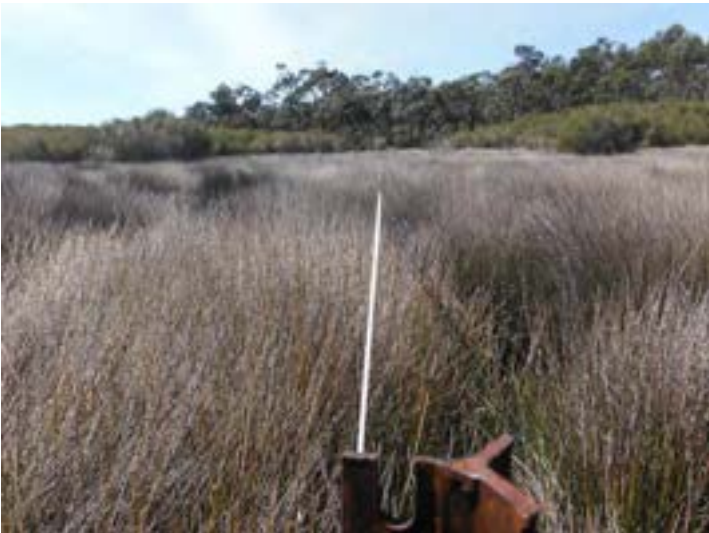
3.2.4 Vegetation and frog site summaries

The following site summaries include:

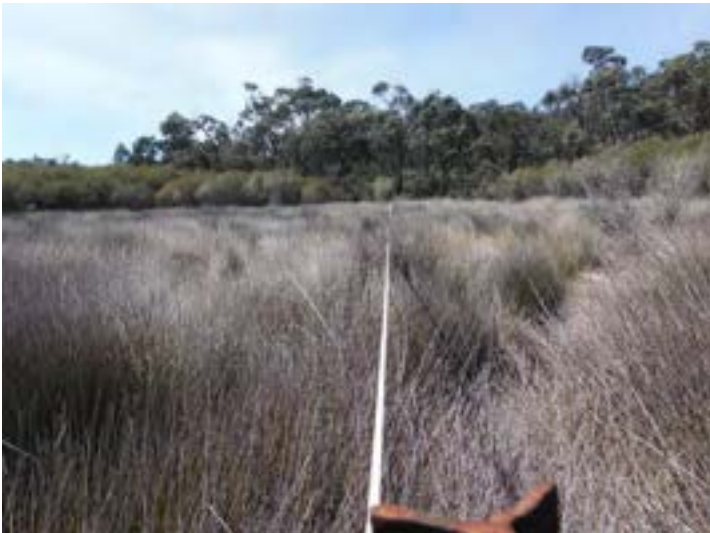
- transect photos at 25 m intervals;
- the proportion of each EVC and each FG recorded at each site;
- the top three dominant plant species and their FG;
- other attributes including average bare ground cover, water depth and algal mat;
- a habitat description;
- frog species occurrence and abundance;
- water quality data; and
- relevant comments.



0—25m



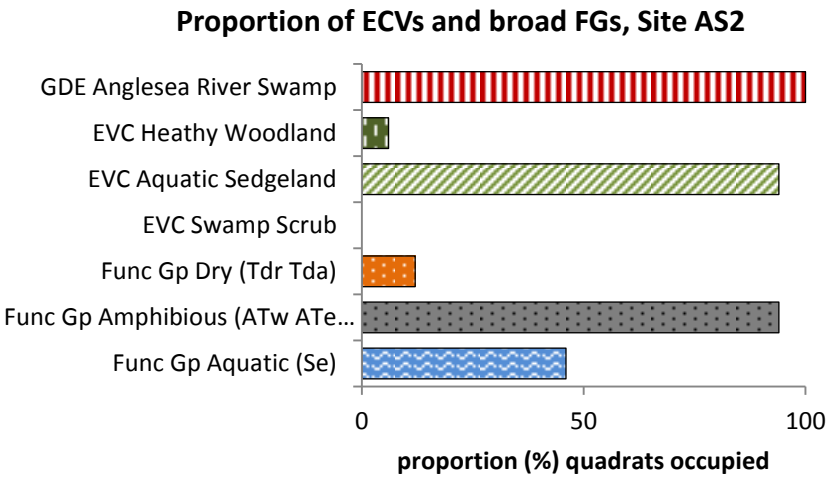
25—50m



50—75m



75—100m



Key:
GDE: Groundwater Dependent Ecosystem
EVC: Ecological Vegetation Class
FG: Functional Group

Dominant Plant Species		Broad FG	Quadrats occupied (% frequency)
<i>Schoenus brevifolius</i>	Zig-zag Bog-sedge	Amphibious	86
<i>Baumea tetragona</i>	Square Twig-sedge	Aquatic	26
<i>Cycnogeton alcockiae</i>	Southern Water-ribbons	Aquatic	26

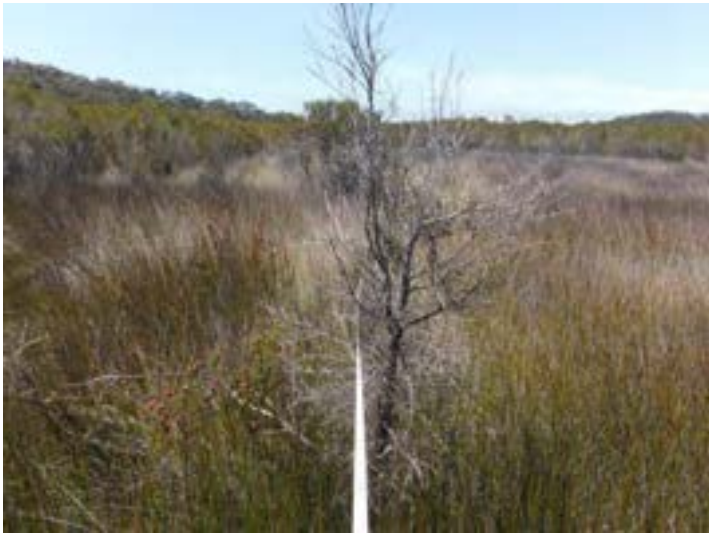
Other attributes		
Average % bare ground cover	0	(bare ground recorded in 0 quadrats)
Average water depth along transect (cm)	5	Water recorded in 36 quadrats
Algal mat (quadrats occupied)	0	

Figure 2 Anglesea Borefield Monitoring and Assessment Program, Anglesea Swamp, Site AS2, vegetation summary data, 2019.



AS2: General habitat description							
Ecological Vegetation Class (EVC)			Aquatic Sedgeland				
Wetland permanence			Ephemeral				
Swamp dominated by emergent dead and live sedges, interspersed with patches of clear open water at varying depth up to c. 15 cm. Open water contains 10–20% floating and submergent vegetation, as well as floating debris. The swamp is fringed with 70–100% shrub vegetation and small amounts of bare wet soil. Macropod and predator scats noted at the swamp.							
AS2: Frog abundance and richness							
Southern Brown Tree Frog		Common Froglet		Southern Bullfrog		Species Richness	
0		0		0		0	
AS2: Water quality parameters							
Survey 1							
pH	3.57	Turbidity	4 NTU	Water temperature		14.6 °C	
EC	3190 µs/cm	Salinity	0.16%	Dissolved Oxygen		1.25 mg/L	
Survey 2							
pH	NA	Turbidity	NA	Water temperature		NA	
EC	NA	Salinity	NA	Dissolved Oxygen		NA	
Comments							
Patches of open water had dried out at the time of the second survey but were still moist underfoot. One Southern Bullfrog calling at least 100 m from observers.							

Figure 3 Anglesea Borefield terrestrial revised ecological Monitoring and Assessment Program, Anglesea Swamp site AS2, 2019 frog summary data.



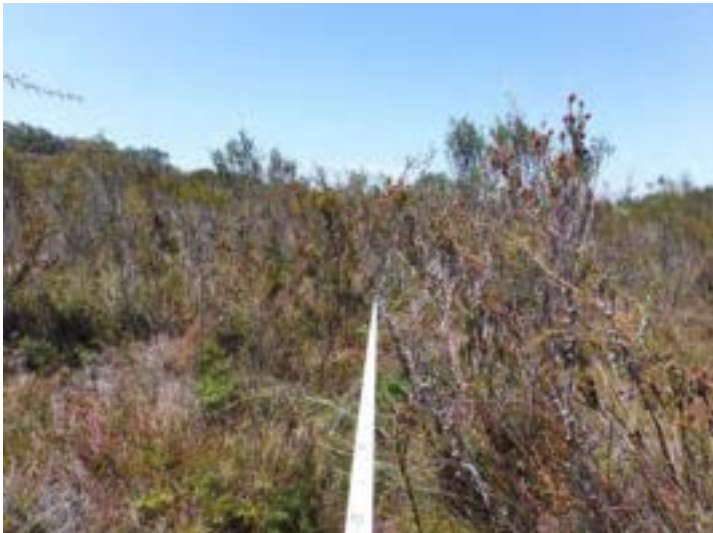
0—25m



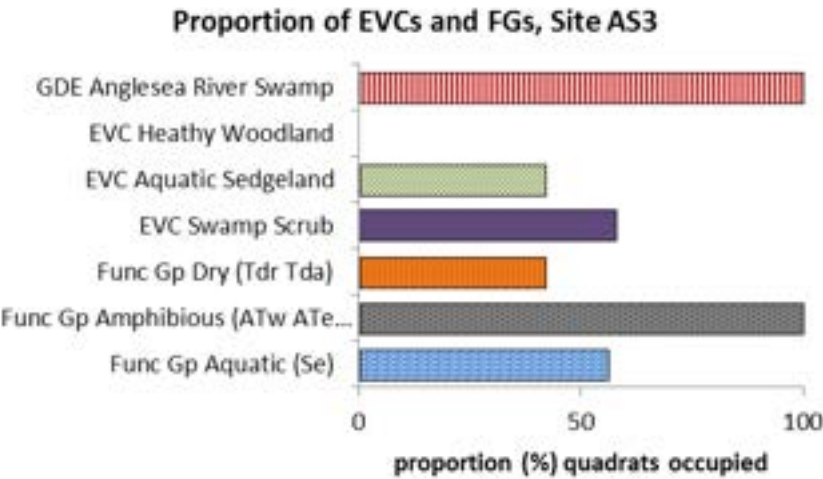
25—50m



50—75m



75—100m



Key:
GDE: Groundwater Dependent Ecosystem
EVC: Ecological Vegetation Class
FG: Functional Group

Dominant Plant Species		Broad FG	Quadrats occupied (% frequency)
Melaleuca squarrosa	Scented Paperbark	Amphibious	66
Schoenus brevifolius	Zig-zag Bog-sedge	Amphibious	64
Baumea tetragona	Square Twig-sedge	Aquatic	56
Sprengalia incarnata	Pink Swamp-heath	Amphibious	56

Other attributes		
Average % bare ground cover	0	(bare ground recorded in 0 quadrats)
Average water depth along transect (cm)	1	Water recorded in 25 quadrats
Algal mat (quadrats occupied)	0	

Figure 4 Anglesea Borefield Monitoring and Assessment Program, Anglesea Swamp, Site AS3, vegetation summary data, 2019.

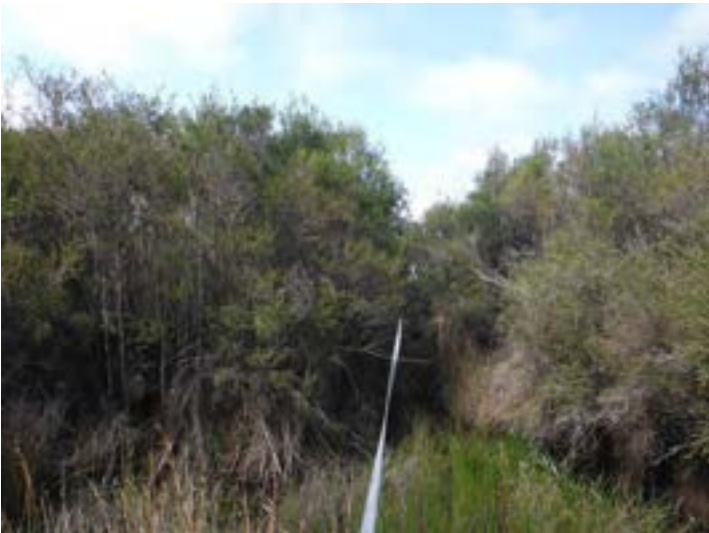


AS3: General habitat description					
Ecological Vegetation Class (EVC)			Swamp Scrub		
Wetland permanence			Semi-permanent		
Small (c. 0.25 ha) clearing in shrub vegetation (Swamp Paperbark, Prickly Tea-tree and Pink Swamp-heath) with c. 100% cover of emergent dead and live sedges and small amounts of Pouched Coral-fern. Less than 5% cover of fallen branches was observed under fringing vegetation. Pools of standing water up to 15 cm deep during the first survey had dried out by the second survey. Shallow water up to 4 cm deep was present in the swamp in the second survey, but no pools.					
AS3: Frog abundance and richness					
Southern Brown Tree Frog		Common Froglet		Southern Bullfrog	
0		0		0	
AS3: Water quality parameters					
Survey 1					
pH	3.43	Turbidity	131 NTU	Water temperature	11.7 °C
EC	801 µs/cm	Salinity	0.03%	Dissolved Oxygen	NA
Survey 2					
pH	3.83	Turbidity	8 NTU	Water temperature	17.8 °C
EC	1440 µs/cm	Salinity	0.06%	Dissolved Oxygen	NA
Comments					
Southern Brown Tree Frogs (1–5 individuals) and Southern Bullfrogs (1–5 individuals) calling at least 100 m from observers.					

Figure 5 Anglesea Borefield terrestrial revised ecological Monitoring and Assessment Program, Anglesea Swamp site AS3, 2019 frog summary data.



0—25m



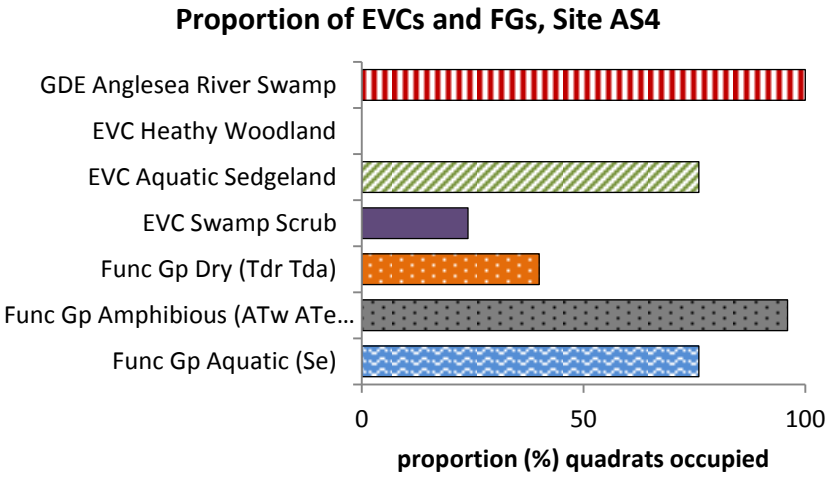
25—50m



50—75m



75—100m



Key:
GDE: Groundwater Dependent Ecosystem
EVC: Ecological Vegetation Class
FG: Functional Group

Dominant Plant Species		Broad FG	Quadrats occupied (% frequency)
<i>Melaleuca squarrosa</i>	Scented Paperbark	Amphibious	92
<i>Cycnogeton procerum</i> sp. aff.	Common Water-ribbons	Aquatic	76
<i>Empodisma minus</i>	Spreading Rope-rush	Amphibious	72

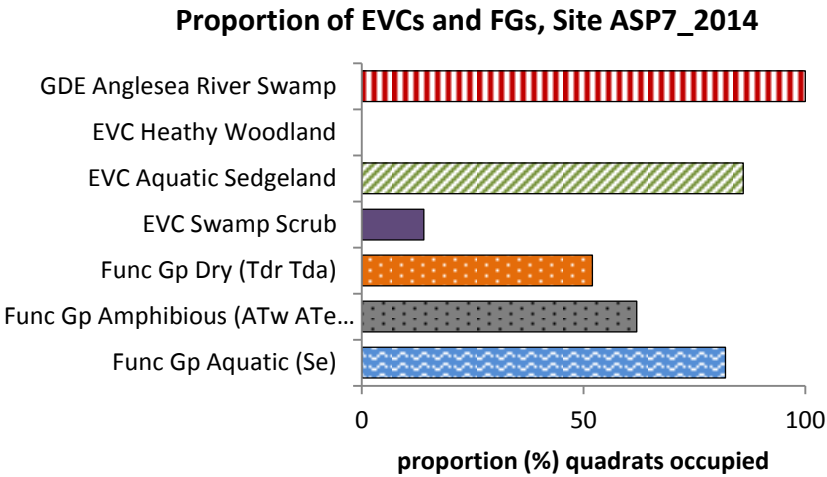
Other attributes		
Average % bare ground cover	0	(bare ground recorded in 0 quadrats)
Average water depth along transect (cm)	2	Water recorded in 30 quadrats
Algal mat (quadrats occupied)	0	

Figure 6 Anglesea Borefield Monitoring and Assessment Program, Anglesea Swamp, Site AS4, vegetation summary data, 2019.



AS4: General habitat description					
Ecological Vegetation Class (EVC)			Aquatic Sedgeland		
Wetland permanence			Semi-permanent		
Survey site located on the perimeter of the swamp in fringing vegetation. Soil was dry and solid underfoot during both surveys. Thick ground cover of Pouched Coral-fern to c. 1 m, with emergent Pink Swamp-heath and Scented Paperbark. Less than 10% cover of fallen branches, and small (5–10%) amounts of bare ground. Macropod scats observed.					
AS4: Frog abundance and richness					
Southern Brown Tree Frog		Common Froglet		Southern Bullfrog	
0		0		0	
AS4: Water quality parameters					
Survey 1					
pH	NA	Turbidity	NA	Water temperature	NA
EC	NA	Salinity	NA	Dissolved Oxygen	NA
Survey 2					
pH	NA	Turbidity	NA	Water temperature	NA
EC	NA	Salinity	NA	Dissolved Oxygen	NA
Comments					
No water quality measurements could be taken given the lack of water at the survey site.					

Figure 7 Anglesea Borefield terrestrial revised ecological Monitoring and Assessment Program, Anglesea Swamp site AS4, 2019 frog summary data.



Key:
GDE: Groundwater Dependent Ecosystem
EVC: Ecological Vegetation Class
FG: Functional Group

Dominant Plant Species		Broad FG	Quadrats occupied (% frequency)
<i>Cynogeton procerum</i> sp. aff.	Common Water-ribbons	Aquatic	76
<i>Baumea arthropphylla</i>	Fine Twig-sedge	Aquatic	72
<i>Schoenus brevifolius</i>	Zig-zag Bog-sedge	Amphibious	58

Other attributes		
Average % bare ground cover	0	(bare ground recorded in 0 quadrats)
Average water depth along transect (cm)	1	Water recorded in 16 quadrats
Algal mat (quadrats occupied)	1	

Figure 8 Anglesea Borefield Monitoring and Assessment Program, Anglesea Swamp, Site ASP7_2014, vegetation summary data, 2019.



ASP7_2014: General habitat description					
Ecological Vegetation Class (EVC)			Aquatic Sedgeland		
Wetland permanence			Ephemeral		
Relatively large (c. 3 ha) clearing in the swamp, comprising c. 90% emergent sedges, fringed with c. 90% cover of mostly Scented Paperbark. At time of second survey, the swamp was mostly dry, with only small pools of up to 5–10 cm deep water remaining. The surface of the swamp was damp and covered in dead and decomposing vegetation. Vehicles had been accessing the site, leaving visible disturbance in the form of numerous tyre tracks.					
ASP7_2014: Frog abundance and richness					
Southern Brown Tree Frog		Common Froglet		Southern Bullfrog	Species Richness
0		0		0	0
ASP7_2014: Water quality parameters					
Survey 1					
pH	2.6	Turbidity	11 NTU	Water temperature	21.7 °C
EC	3400 µs/cm	Salinity	0.17%	Dissolved Oxygen	NA
Survey 2					
pH	3.34	Turbidity	NA	Water temperature	26.7 °C
EC	2280 µs/cm	Salinity	0.11%	Dissolved Oxygen	NA
Comments					
Pools of up to 20 cm depth were present during the first survey, but water too shallow for turbidity or dissolved oxygen measurements during the second survey. Southern Bullfrog (1–5 individuals) heard calling at least 100 m from observers.					

Figure 9 Anglesea Borefield terrestrial revised ecological Monitoring and Assessment Program, Anglesea Swamp site ASP7_2014, 2019 frog summary data.



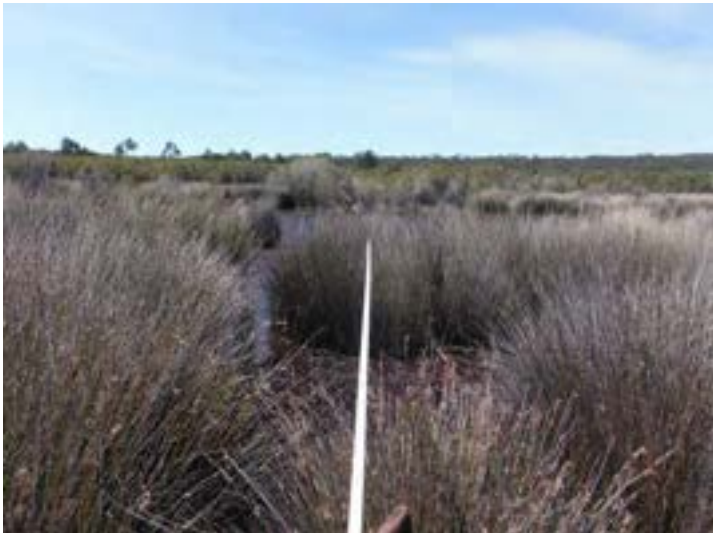
0—25m



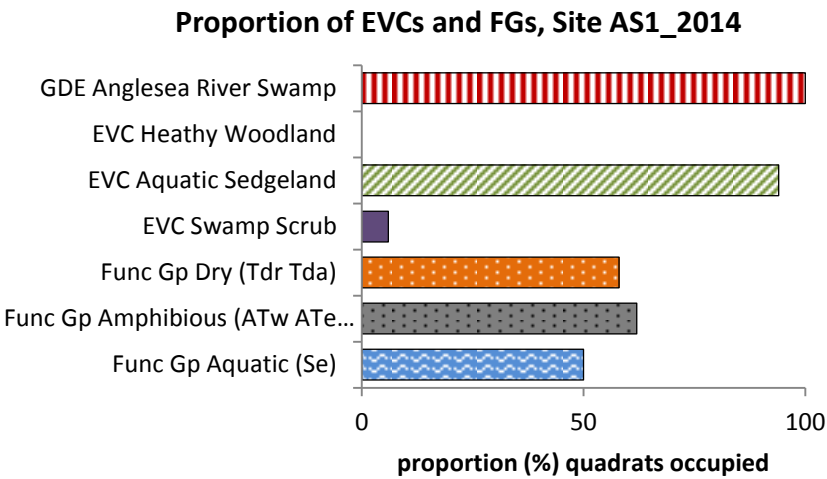
25—50m



50—75m



75—100m



Key:
GDE: Groundwater Dependent Ecosystem
EVC: Ecological Vegetation Class
FG: Functional Group

Dominant Plant Species		Broad FG	Quadrats occupied (% frequency)
<i>Cynogeton procerum</i> sp. aff.	Common Water-ribbons	Aquatic	50
<i>Baumea arthropphylla</i>	Fine Twig-sedge	Aquatic	50
<i>Schoenus brevifolius</i>	Zig-zag Bog-sedge	Amphibious	48

Other attributes		
Average % bare ground cover	0	(bare ground recorded in 0 quadrats)
Average water depth along transect (cm)	9	Water recorded in 46 quadrats
Algal mat (quadrats occupied)	44	

Figure 10 Anglesea Borefield Monitoring and Assessment Program, Anglesea Swamp, Site AS1_2014, vegetation summary data, 2019.



AS1_2014: General habitat description					
Ecological Vegetation Class (EVC)			Aquatic Sedgeland		
Wetland permanence			Ephemeral		
Mostly open swamp almost completely fringed with Scented Paperbark and Prickly Tea-tree. During the first survey, the swamp supported up to 10 cm of water, containing 70–100% cover of floating red filamentous algae, which had dried to a black crust in drier areas. Some emergent rushes (20–50%) occurred in patches through the swamp, with sporadic submergent cover of Common Water-ribbons (c. 5%). Small amounts of bare soil and dead branches were observed around the edges of the swamp. Some wallaby tracks and scats were also observed.					
AS1_2014: Frog abundance and richness					
Southern Brown Tree Frog		Common Froglet		Southern Bullfrog	
Species Richness					
0		0		0	
AS1_2014: Water quality parameters					
Survey 1					
pH	8.1	Turbidity	8 NTU	Water temperature	23.7 °C
EC	4540 µs/cm	Salinity	0.23%	Dissolved Oxygen	7.5 mg/L
Survey 2					
pH	NA	Turbidity	NA	Water temperature	NA
EC	NA	Salinity	NA	Dissolved Oxygen	NA
Comments					
AS1_2014 did not support standing water at the time of the second survey. The swamp surface was soft and wet underfoot. One Southern Bullfrog was calling very infrequently during the first survey, at least 100 m from observers.					

Figure 11 Anglesea Borefield terrestrial revised ecological Monitoring and Assessment Program, Anglesea Swamp site AS1_2014, 2019 frog summary data.



0—25m



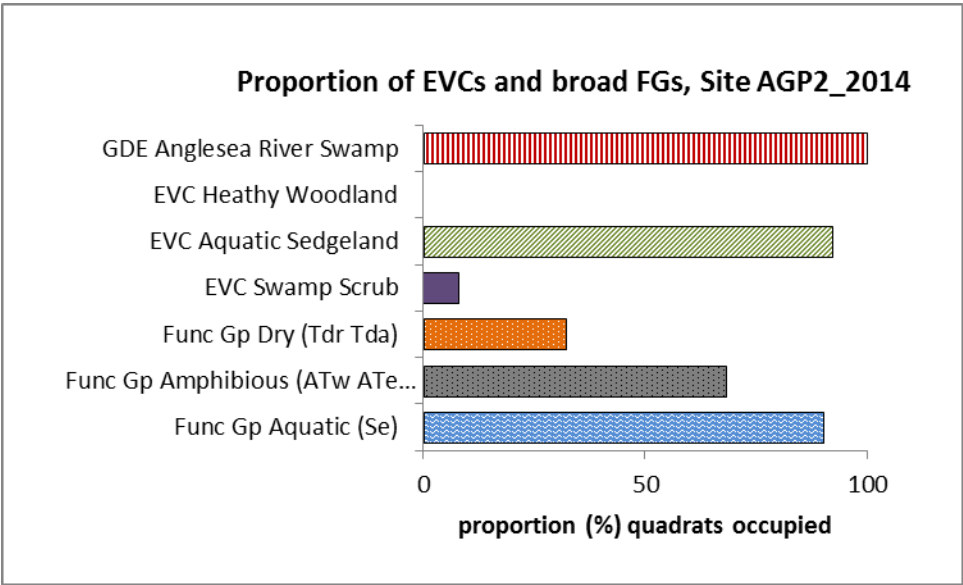
25—50m



50—75m



75—100m



Key:
GDE: Groundwater Dependent Ecosystem
EVC: Ecological Vegetation Class
FG: Functional Group

Dominant Plant Species		Broad FG	Quadrats occupied (% frequency)
<i>Cynogeton procerum</i> sp. aff.	Common Water-ribbons	Aquatic	90
<i>Juncus procerus</i>	Tall Rush	Amphibious	62
<i>Melaleuca squarrosa</i>	Scented Paperbark	Amphibious	56

Other attributes		
Average % bare ground cover	0	(bare ground recorded in 0 quadrats)
Average water depth along transect (cm)	0.2	Water recorded in 48 quadrats
Algal mat (quadrats occupied)	32	

Figure 12 Anglesea Borefield Monitoring and Assessment Program, Anglesea Swamp, Site AGP2_2014, vegetation summary data, 2019.



AGP2_2014: General habitat description					
Ecological Vegetation Class (EVC)			Aquatic Sedgeland		
Wetland permanence			Ephemeral		
Small (c. 0.25 ha) clearing in tall (up to 4 m) fringing vegetation of Scented Paperbark and Prickly Tea-tree. Approximately 40% open water with c. 20–50% cover of floating Common Water-ribbons, interspersed with emergent rushes and patches of Scented Paperbark. Water at time of first survey was clear, with decomposing Water-ribbons, leaves and woody debris present. Pools up to 20 cm at time of first survey had dried out to less than 5 cm at time of second survey.					
AGP2_2014: Frog abundance and richness					
Southern Brown Tree Frog		Common Froglet		Southern Bullfrog	Species Richness
0		0		0	0
AGP2_2014: Water quality parameters					
Survey 1					
pH	2.84	Turbidity	2 NTU	Water temperature	20.1 °C
EC	4010 µs/cm	Salinity	0.2%	Dissolved Oxygen	6.8 mg/L
Survey 2					
pH	NA	Turbidity	NA	Water temperature	NA
EC	NA	Salinity	NA	Dissolved Oxygen	NA
Comments					
Insufficient water was present for water quality measurements during second survey. Southern Brown Tree Frogs (1–5 individuals) were calling during the first survey, at least 100 m from observers, towards the south-east.					

Figure 13 Anglesea Borefield terrestrial revised ecological Monitoring and Assessment Program, Anglesea Swamp site AGP2_2014, 2019 frog summary data.



AS5: General habitat description					
Ecological Vegetation Class (EVC)			Aquatic Sedgeland		
Wetland permanence			Ephemeral		
Dry swamp, less than 0.25 ha in size, with complete cover of vegetation, comprising sedges and Pouched Coral-fern, surrounded by 100% cover of fringing Prickly Tea-tree and Scented Paperbark. Swamp dry underfoot, with thick cover of dead sedges and 5–10% cover of fallen branches around the perimeter of the swamp.					
AS5: Frog abundance and richness					
Southern Brown Tree Frog		Common Froglet		Southern Bullfrog	Species Richness
0		0		0	0
AS5: Water quality parameters					
Survey 1					
pH	NA	Turbidity	NA	Water temperature	NA
EC	NA	Salinity	NA	Dissolved Oxygen	NA
Survey 2					
pH	NA	Turbidity	NA	Water temperature	NA
EC	NA	Salinity	NA	Dissolved Oxygen	NA
Comments					
The swamp was dry during both surveys; hence no water quality measurements were taken.					

Figure 14 Anglesea Borefield terrestrial revised ecological Monitoring and Assessment Program, Anglesea Swamp site AS5, 2019 frog summary data.

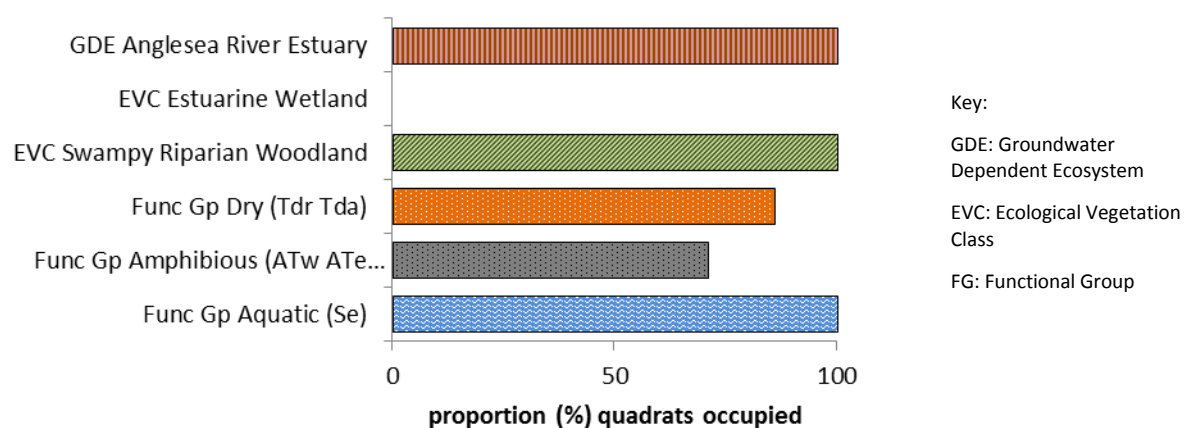


AS6: General habitat description					
Ecological Vegetation Class (EVC)			Aquatic Sedgeland		
Wetland permanence			Ephemeral		
Swamp clearing, damp underfoot with maximum 5 cm of water in small pools. Swamp vegetation mostly comprises 70–100% cover of decomposing sedges, with small clumps of live sedges and Scented Paperbark. The swamp is fringed by 70–100% cover of Scented Paperbark. Runnels through the swamp contain dead vegetation, small amounts of water, algae and sprouting sedges. The perimeter of the swamp supports <5% cover of fallen branches and 5–10% cover of bare soil. Some macropod scats observed at the site.					
AS6: Frog abundance and richness					
Southern Brown Tree Frog		Common Froglet		Southern Bullfrog	Species Richness
0		0		0	0
AS6: Water quality parameters					
Survey 1					
pH	NA	Turbidity	NA	Water temperature	NA
EC	NA	Salinity	NA	Dissolved Oxygen	NA
Survey 2					
pH	NA	Turbidity	NA	Water temperature	NA
EC	NA	Salinity	NA	Dissolved Oxygen	NA
Comments					
Water quality was not measured during either survey due to insufficient depth.					

Figure 15 Anglesea Borefield terrestrial revised ecological Monitoring and Assessment Program, Anglesea Swamp site AS6, 2019 frog summary data.



Proportion of EVCs and broad FGs, Site LAR1



Dominant native plant species		Broad FG	Quadrats occupied (% frequency)
<i>Cychnogeton alcockiae</i>	Southern Water-ribbons	Aquatic	86
<i>Eucalyptus ovata</i> var. <i>ovata</i>	Swamp Gum	Dry	86
<i>Leptospermum scoparium</i>	Manuka	Dry	57

Other attributes	
Average % bare ground cover	0
Algal mat	1

Figure 16 Anglesea Borefield Monitoring and Assessment Program, Anglesea Estuary, Site LAR1, vegetation summary data, 2019.

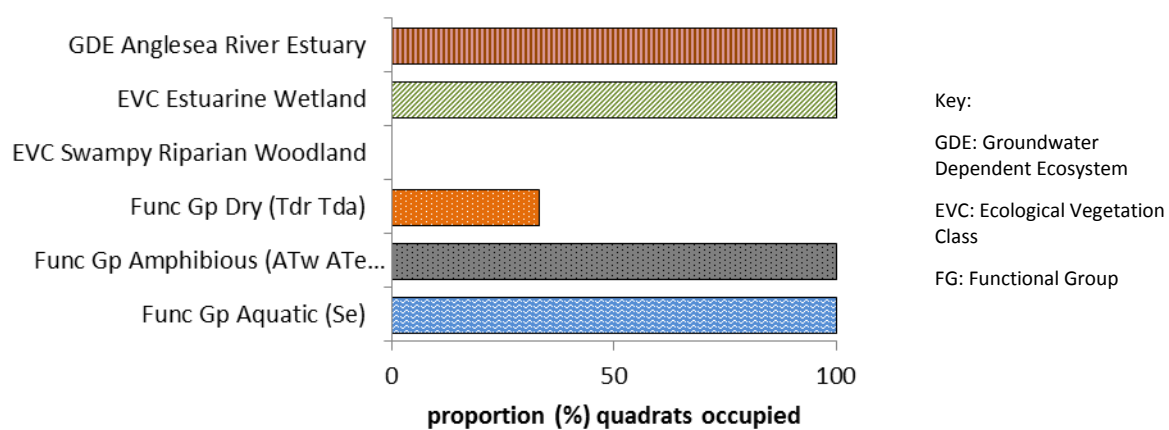


LAR1: General habitat description						
Ecological Vegetation Class (EVC)			Swampy Riparian Woodland			
Wetland permanence			Permanent			
Slow-flowing creek between 30–100 cm deep and up to 3 m wide, with 20–50% cover of submergent algae and Southern Water-ribbons and 10–20% floating cover of water-ribbons. Creek fringed with young Common Reeds, water-ribbons and revegetation including Prickly Tea-tree, Eucalypts and Goodenia. Common Reeds also present as emergent vegetation on the banks.						
LAR1: Frog abundance and richness						
Southern Brown Tree Frog		Common Froglet		Southern Bullfrog		Species Richness
0		0		0		0
LAR1: Water quality parameters						
Survey 1						
pH	3.32	Turbidity	1 NTU	Water temperature		15.2 °C
EC	4810 µs/cm	Salinity	0.24%	Dissolved Oxygen		4.82 mg/L
Survey 2						
pH	3.84	Turbidity	0 NTU	Water temperature		21.2 °C
EC	13800 µs/cm	Salinity	0.79%	Dissolved Oxygen		6.97 mg/L
Comments						
Southern Brown Tree Frogs (1–5 individuals) were heard calling during the first survey, more than 100 m upstream from the site.						

Figure 17 Anglesea Borefield terrestrial revised ecological Monitoring and Assessment Program, Anglesea Estuary site LAR1, 2019 frog summary data.



Proportion of EVCs and broad FGs, Site LAR2



Dominant native plant species		Broad FG	Quadrats occupied (% frequency)
<i>Juncus kraussii</i> ssp. <i>australiensis</i>	Sea Rush	Aquatic	100
<i>Phragmites australis</i>	Common Reed	Amphibious	80
<i>Selliera radicans</i>	Shiny Swamp-mat	Amphibious	80

Other attributes	
Average % bare ground cover	0
Algal mat	0

Figure 18 Anglesea Borefield Monitoring and Assessment Program, Anglesea Estuary, Site LAR2, vegetation summary data, 2019.

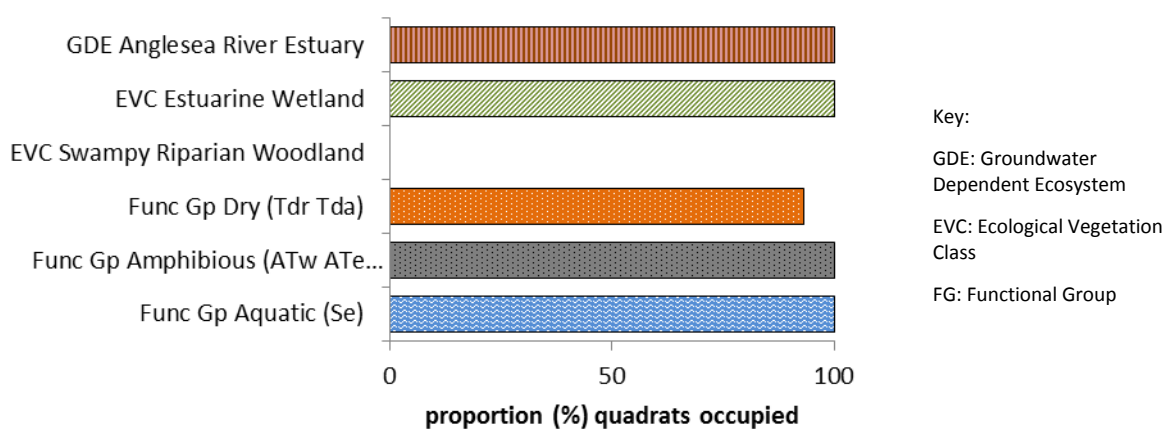


LAR2: General habitat description					
Ecological Vegetation Class (EVC)			Estuarine Woodland		
Wetland permanence			Permanent		
Slow-moving creek in estuary, up to 2 m deep and 7 m wide, fringed with 70–100% cover of Coastal Tussock-grass, Sea Rush and Common Reed. Submergent vegetation comprises 5–10% cover of dead reeds and algae. The site is mostly open, supporting less than 5% cover of emergent vegetation.					
LAR2: Frog abundance and richness					
Southern Brown Tree Frog		Common Froglet		Southern Bullfrog	
0		0		0	
LAR2: Water quality parameters					
Survey 1					
pH	3.67	Turbidity	6 NTU	Water temperature	19.9 °C
EC	9500 µs/cm	Salinity	0.53%	Dissolved Oxygen	9.3 mg/L
Survey 2					
pH	3.86	Turbidity	0 NTU	Water temperature	21.2 °C
EC	14400 µs/cm	Salinity	0.84%	Dissolved Oxygen	7.89 mg/L
Comments					
Southern Brown Tree Frogs (1–5) and Southern Bullfrogs (1–5) were heard calling during the first survey, more than 100 m from observers.					

Figure 19 Anglesea Borefield terrestrial revised ecological Monitoring and Assessment Program, Anglesea Estuary site LAR2, 2019 frog summary data.



Proportion of EVCs and broad FGs, Site LAR3



Dominant native plant species		Broad FG	Quadrats occupied (% frequency)
<i>Juncus kraussii</i> ssp. <i>australiensis</i>	Sea Rush	Aquatic	100
<i>Cynogeton procerum</i> sp. aff.	Common Water-ribbons	Aquatic	87
<i>Poa poiformis</i> var. <i>poiformis</i>	Coast Tussock-grass	Dry	87

Other attributes	
Average % bare ground cover	0
Algal mat	0

Figure 20 Anglesea Borefield Monitoring and Assessment Program, Anglesea Estuary, Site LAR3, vegetation summary data, 2019.

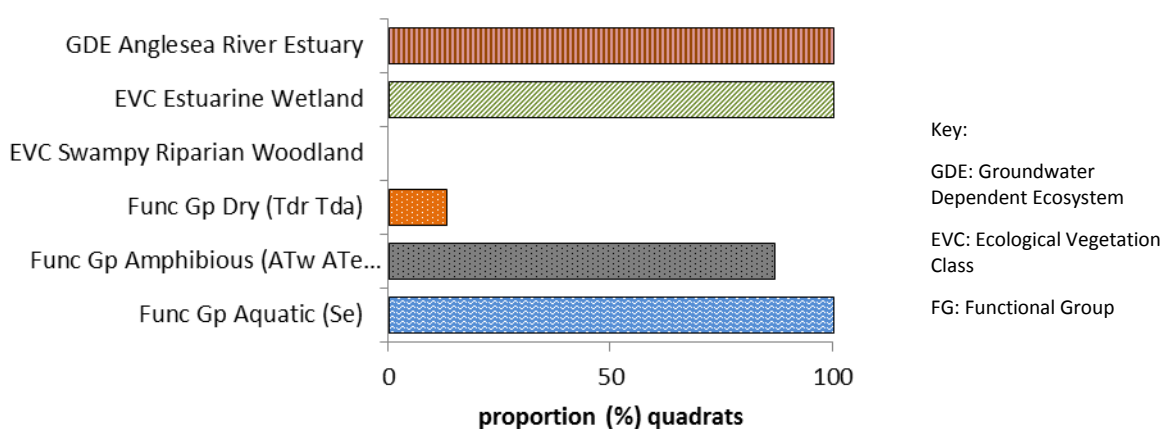


LAR3: General habitat description					
Ecological Vegetation Class (EVC)			Estuarine Woodland		
Wetland permanence			Permanent		
Slow-flowing creek c. 8 m wide and up to 2 m deep. Water is relatively clear, with 5–10% floating and 5–10% submergent vegetation, comprising Common Water-ribbons, Common Reed, Sedges and algae. Low (5–10%) cover of emergent reeds and water-ribbons emerge near the banks. Bare soil, debris and fallen branches occur on the banks, and the site is fringed by 70–100% cover of vegetation including Sea Rush, Common Water-ribbons and Shiny Swamp-mat.					
LAR3: Frog abundance and richness					
Southern Brown Tree Frog		Common Froglet		Southern Bullfrog	
0		0		1	
LAR3: Water quality parameters					
Survey 1					
pH	3.7	Turbidity	7 NTU	Water temperature	20.0 °C
EC	9300 µs/cm	Salinity	0.52%	Dissolved Oxygen	9.54 mg/L
Survey 2					
pH	3.94	Turbidity	0 NTU	Water temperature	21.1 °C
EC	14400 µs/cm	Salinity	0.84%	Dissolved Oxygen	8.47 mg/L
Comments					
Southern Brown Tree Frogs (1–5) were heard calling during the first survey, more than 100 m from observers. One Southern Bullfrog observed near on the path near the site during the second survey.					

Figure 21 Anglesea Borefield terrestrial revised ecological Monitoring and Assessment Program, Anglesea Estuary site LAR3, 2019 frog summary data.



Proportion of EVCs and broad FGs, Site LAR4



Dominant native plant species		Broad FG	Quadrats occupied (% frequency)
<i>Juncus kraussii</i> ssp. <i>australiensis</i>	Sea Rush	Aquatic	100
<i>Cynogeton procerum</i> sp. aff.	Common Water-ribbons	Aquatic	100
<i>Selliera radicans</i>	Shiny Swamp-mat	Amphibious	73

Other attributes	
Average % bare ground cover	0
Algal mat	0

Figure 22 Anglesea Borefield Monitoring and Assessment Program, Anglesea Estuary, Site LAR4, vegetation summary data, 2019.



LAR4: General habitat description							
Ecological Vegetation Class (EVC)			Heathy Woodland				
Wetland permanence			Permanent				
Wide (up to 9 m) creek, up to 2 m deep, fringed by 70–100% cover of revegetation on the west bank (Prickly Tea-tree, Goodenia etc) and by Sea Rush, dead Common Reed and Coastal Tussock-grass on the east bank. Algae forms dense submerged mats on the bank, with decomposing and emergent sedges and reeds. Low (<5%) submergent and floating cover of Common Water-ribbons, Sea Rush, algae and dead vegetation.							
LAR4: Frog abundance and richness							
Southern Brown Tree Frog		Common Froglet		Southern Bullfrog		Species Richness	
0		0		0		0	
LAR4: Water quality parameters							
Survey 1							
pH	3.74	Turbidity	11 NTU	Water temperature		20.2 °C	
EC	9700 µs/cm	Salinity	0.54%	Dissolved Oxygen		9.38 mg/L	
Survey 2							
pH	3.93	Turbidity	0 NTU	Water temperature		21.2 °C	
EC	14500 µs/cm	Salinity	0.84%	Dissolved Oxygen		8.3 mg/L	
Comments							
Southern Brown Tree Frogs (6–10) and Southern Bullfrogs (6–10) were heard calling during the first survey, at least 100 m from observers.							

Figure 23 Anglesea Borefield terrestrial revised ecological Monitoring and Assessment Program, Anglesea Estuary site LAR4, 2019 frog summary data.



Figure 24 Anglesea Borefield ecological Monitoring and Assessment Program, wetland boundaries, sites AS2, AS3 and AS4, Anglesea Swamp 2019.



Figure 25 Anglesea Borefield ecological Monitoring and Assessment Program, wetland boundaries, sites ASP7_2014, AS1_2014 NS, AGP2_2014, Anglesea Swamp 2019.

3.3 Macroinvertebrates

The macroinvertebrate site results based on combined data from each site sampled are provided in Table 6, for comparison against previous results (GHD 2010–2017, Ecology Australia 2018, 2019).

None of the samples collected contained sufficient macroinvertebrates to enable the sample to be picked in 30 minutes (each one had considerably less than 200 macroinvertebrates). BCT1 had insufficient surface water for three samples to be collected. Two sites were so depauperate that the combined data from all samples did not add up to 200 macroinvertebrates.

Site W2/3 had the fewest taxa present, with only nine taxa detected across the three samples, and in one sample only four taxa were detected. This is substantially less than the State Environmental Protection Policy (SEPP) – Waters of Victoria (WoV) objective (Vic. Gov. 2003) of 24 taxa. No samples attained SEPP objectives for number of taxa, and even as combined samples by site there were no sites that achieved this objective.

None of the sites attained SEPP–WoV objectives for EPA key families, despite being triplicate rather than dual samples, with W2/3 again performing considerably worse than all other sampled sites. As combined sample sites, the highest number of taxa detected was 19, which occurred at SC1.

Two sites attained SEPP–WoV objectives for SIGNAL scores when the three samples were combined, with BCT1 attaining the highest score. BCT1 and SC1 attained the highest diversity for EPT and EPTO, but still failed to meet the SEPP–WoV objectives.

Table 6 Site macroinvertebrate indices results (non-attainment of SEPP WoV objectives indicated by shading)

Indices	W2/3	SC1	BCT1	SEPP objective*
# taxa	9	19	13	24
Abundance	174	223	102	N/A
EPA key families	6	13	8	26*
SIGNAL score	5.1	5.8	5.9	5.8
EPT	0	4	4	9
EPTO	0	4	4	N/A

3.4 Southern Pygmy Perch

A total of 11 Southern Pygmy Perch were captured from Salt Creek (SC1), and none were captured from Breakfast Creek tributary (BCT1) (Figure 26 and Figure 27, Plate 4). These represent the third lowest and equal lowest spring Catch Per Unit Effort (CPUE) since 2009, respectively. CPUE was calculated using number of traps deployed, based on the assumption that five bait traps were utilised each spring from 2009–2016, and ten traps were utilised from 2017–2019. It is unclear how many of the fish were detected via electrofishing versus bait traps in 2009 and 2010, or how many bait traps were used between 2012 and 2016 as it is not specified in the methods (GHD 2010–2017). While CPUE is typically

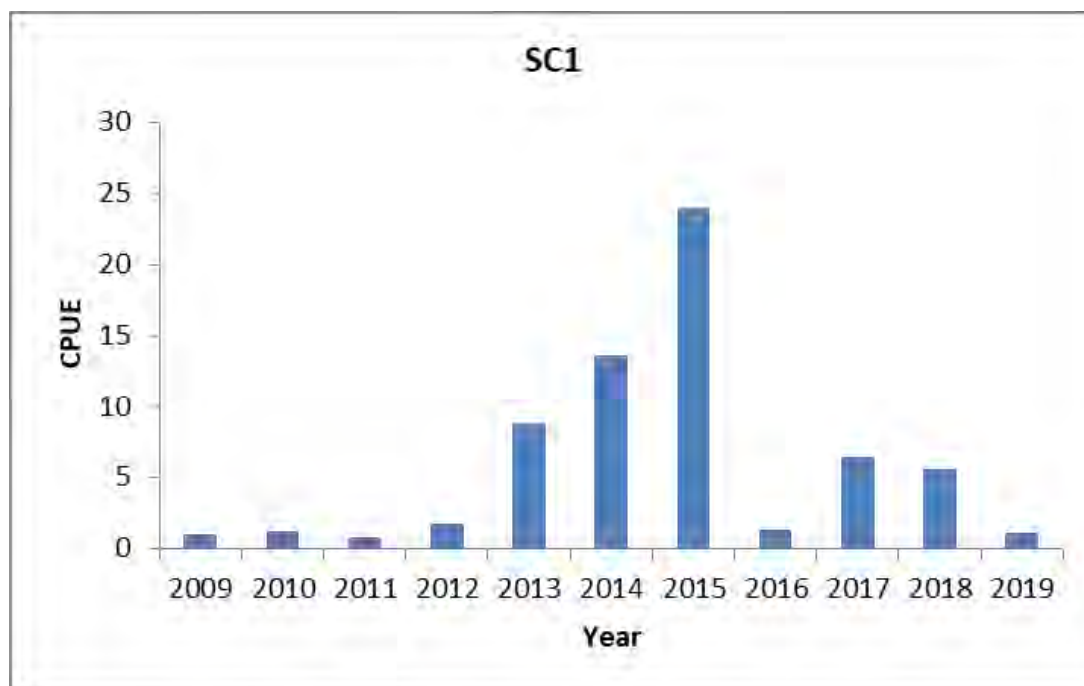
measured by units of time, this was not feasible due to the lack of data from previous years, so catch per trap was used instead.

Higher total abundances had been noted from BCT1 in 2015–2017, followed by a reduction to zero fish detected in 2018 and 2019. Recruitment was last detected in spring 2016 (GHD 2017), which means there have been three successive spring sampling events where recruitment has not been detected. However, the detection of recent recruitment for this and most Victorian freshwater fish species is more reliably detected by sampling fish in autumn, rather than spring. Although no fish were detected at this site during the two most recent rounds of monitoring, it should be noted that none were detected in spring 2012, and the population was redetected at the site the following autumn.

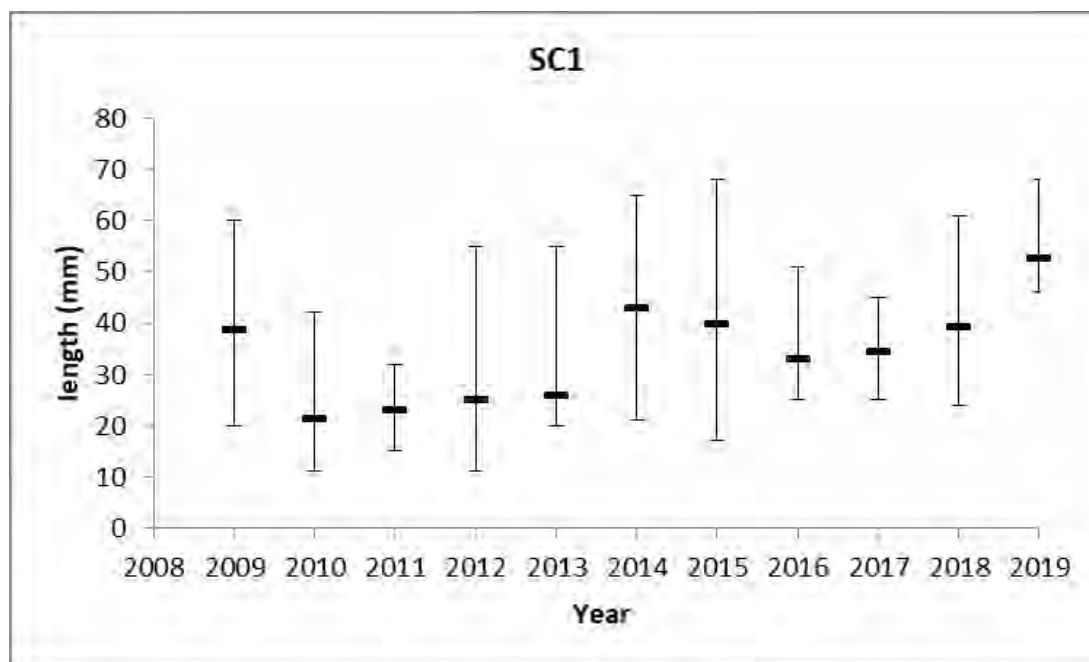
The abundance of Southern Pygmy Perch in SC1 appears to have been highly variable over the 11 years of monitoring. Recruitment appears to have occurred annually at SC1 from 2009–2018; however, no recruitment was detected in 2019.



Plate 4 Southern Pygmy Perch from SC1

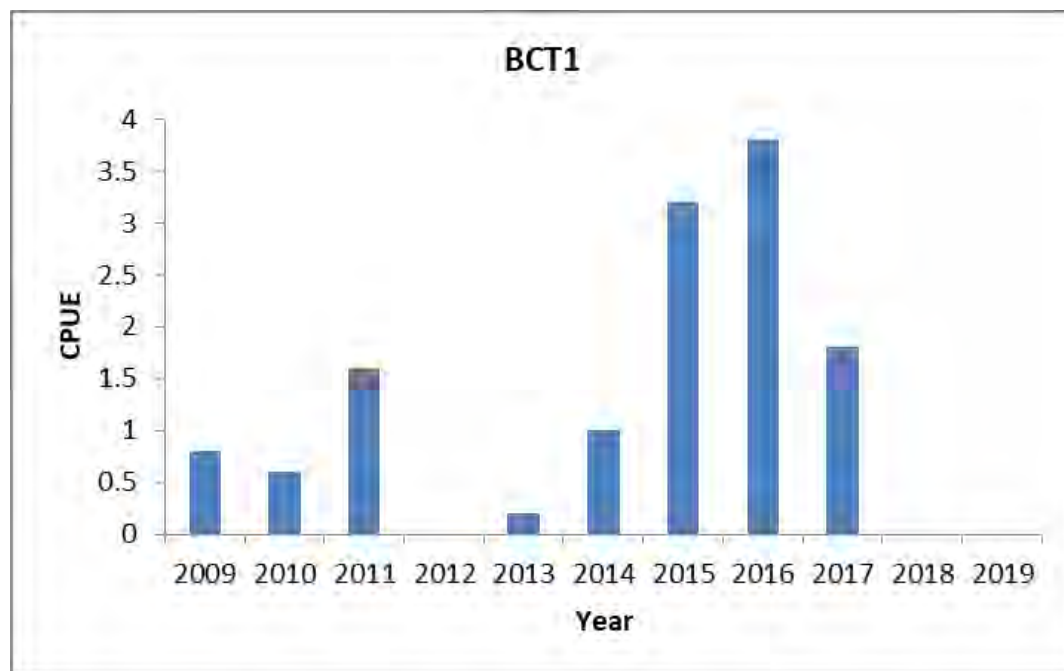


a) Fish Catch Per Unit Effort (CPUE)(fish per trap) at SC1.

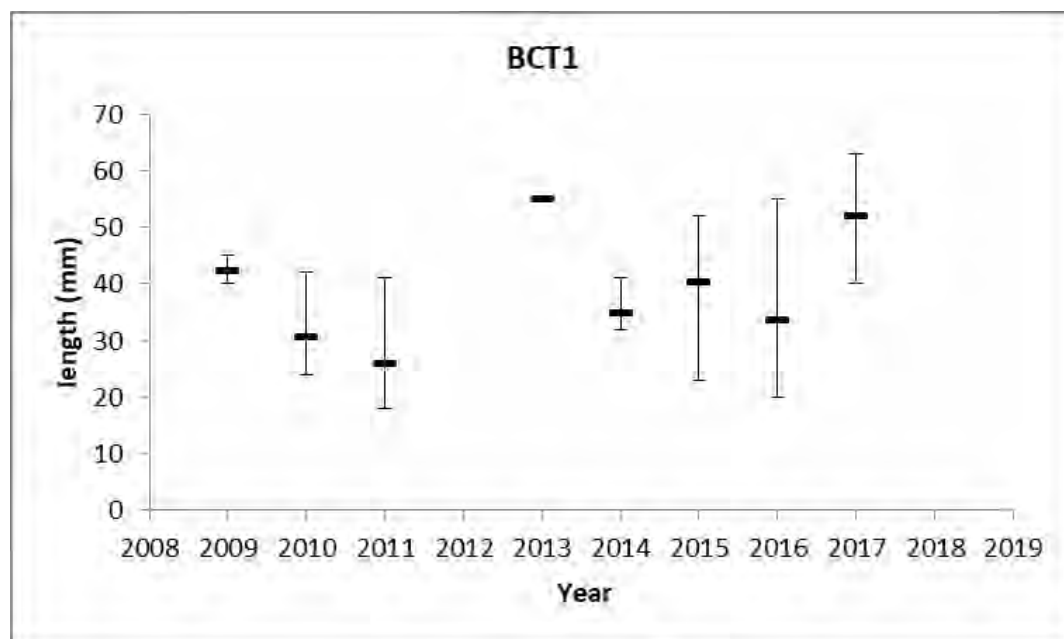


b) Mean (black bars), together with minimum and maximum lengths (TL) of Southern Pygmy Perch. n= CPUE x5 from Figure 27a), with the exception of 2017–2019 where n=CPUEx10

Figure 26 Site SC1 Southern Pygmy Perch spring CPUE a), and length (TL) b) summary 2009–2019



a) Fish Catch Per Unit Effort (CPUE)(fish per trap) at BCT1



b) Mean (black bars), together with minimum and maximum lengths (TL) of Southern Pygmy Perch. $n = \text{CPUE} \times 5$ from Figure 27a), with the exception of 2017–2019 where $n = \text{CPUE} \times 10$

Figure 27 Site BCT1 Southern Pygmy Perch spring CPUE a), and length (TL) b) summary 2009–2019

3.5 Water quality

Water quality results were fairly consistent with results from previous years (GHD 2010–17, Ecology Australia 2018, 2019) (Table 7). It should be noted that to accurately assess against SEPP-WoV indices, a minimum of 11 data points are required from a single year, hence snap-shot measurements are incapable of providing an indication of compliance. The SEPP-W objectives are compared against the results only to provide context.

Table 7 In situ water quality results and SEPP-W objectives

	Temperature (°C)	Conductivity (s/cm)	Dissolved oxygen		pH
			mg/L	%Sat	
SEPP-W objective		<200 (75 th percentile)		>85 (25 th percentile)	6.5-7.5 (25 th -75 th percentile)
BCT1	11.16	394	7.20	67.8	4.30
SC1	11.87	341	4.71	45.1	4.78
W2&3	10.99	5310	5.07	48.3	2.36

3.6 Otway Bush Yabby

Otway Bush Yabby *Geocharax tasmanicus* (formerly *G. gracilis*) is a small freshwater crayfish listed as Endangered on the Victorian Advisory List of threatened invertebrates (DSE 2009). Otway Bush Yabby was detected at two of the three surveys locations where the species has been detected annually since 2017 (Ecology Australia 2018, 2019). Otway Bush Yabby were detected during both the fish survey (bait trapping), and the macroinvertebrate survey (dip netting) (Table 8). A total of 61 individuals were detected. There is a published record from Salt Creek c.2007 (Schultz et al. 2007).

Table 8 Records of Otway Bush Yabby (spring 2019)

Site	Macroinvertebrate sampling	Bait trapping
BCT1	37	20 (male, female, juveniles)
SC1	3	1 (female)
W2&3	0	



Plate 5 Otway Bush Yabby, mature and juvenile specimens – Breakfast Creek tributary (BCT1)



Plate 6 Otway Bush Yabby – Breakfast Creek tributary (BCT1)

3.7 Aquatic monitoring sites

Wetland 2 and 3



Plate 7 Wetland 2 and 3

At the time of survey, Wetlands 2 and 3 were very shallow, contracted, and dominated by dense stands of Paperbark and Tea-tree. These two wetlands are connected and hence do not constitute independent sites. Additionally, at the time of survey there was insufficient surface water present in either wetland to collect three samples, so Wetlands 2 and 3 were converted to a single site, which is consistent with the previous two years of monitoring.

The substrate was predominantly clay/silt, with a gravel track running adjacent to the site and presenting a potential point source of pollutants and sediment. Filamentous algae was abundant, and macrophytes and coarse particulate organic matter were present in moderate abundance. The majority of the site exhibited no obvious flow, with the exception of slow flow being evident within a small channel crossing under the track. Despite combining the two wetlands, this site had very limited standing water. At the time of sampling, the in situ water quality measurements appeared poor relative to SEPP objectives.

The macroinvertebrate results for the wetland site were poor for all indices (Table 9). Site W2/3 has regularly been dry at the time of survey, or an alternative wetland site has been surveyed.

Macroinvertebrate sampling results from Wetland 2/3 were broadly similar with the most recent survey in 2018 (Ecology Australia 2019).

Table 9 Individual macroinvertebrate sample results at W2/3, showing SEPP-W objectives (shading indicates non-attainment of SEPP objectives)

	W2/3-1	W2/3-2	W2/3-3	SEPP-W objective
# taxa	5	6	4	17
Abundance	81	38	55	-
SIGNAL2	3.0	3.2	2.8	4.2
EPT	0	0	0	6
EPTO	0	0	0	-

Salt Creek (SC1)



Plate 8 Salt Creek at SC1

Salt Creek at SC1 had the largest areas of surface water available for sampling, and appeared permanent. The substrate was silt/clay, and the site was dominated by lentic (still) habitats. The main instream cover available for fish and macroinvertebrates, in decreasing order of prevalence, consisted of loose silt lying on the surface, Coarse Particulate Organic Matter (CPOM)(e.g. leaves, branches and other organic debris), overhanging terrestrial vegetation, aquatic vegetation, overhanging bank and logs. The dominant aquatic vegetation taxa were *Juncus* spp., *Carex* spp. and *Blechnum nudum*.

Salt Creek failed to attain SEPP objectives for all macroinvertebrate indices with the exception of the SIGNAL2 score for two of the three samples (Table 10). SC1 has been surveyed annually, and was last surveyed in 2018 (Ecology Australia 2019). The pH, conductivity, and dissolved oxygen levels have deteriorated slightly since 2018, while the macroinvertebrate results are comparable or showed slight improvements against all indices.

Table 10 Individual macroinvertebrate sample results at SC1, showing SEPP-W objectives (shading indicates non-attainment of SEPP objectives)

	SC1-1	SC1-2	SC1-3	SEPP-W objective
# taxa	14	7	14	17
Abundance	67	30	51	-
SIGNAL2	4.8	4.3	3.6	4.2
EPT	4	1	1	6
EPTO	4	1	1	-

Total abundance of Southern Pygmy Perch was lower than it has been since 2016 and CPUE was lower than it has been since 2011. The length-frequency histogram shows a population dominated by older fish and indicates possible recruitment failure or very low levels of recruitment in the past 12 months. Southern Pygmy Perch reach maturity at approximately 30–33 mm (Knight 2008), and the smallest length detected was 46 mm (Figure 28). It should be noted that fish growth rates can be influenced by a number of factors including temperature and resource availability, hence using recruitment or length at maturity cut-off lengths provide only a coarse indication.

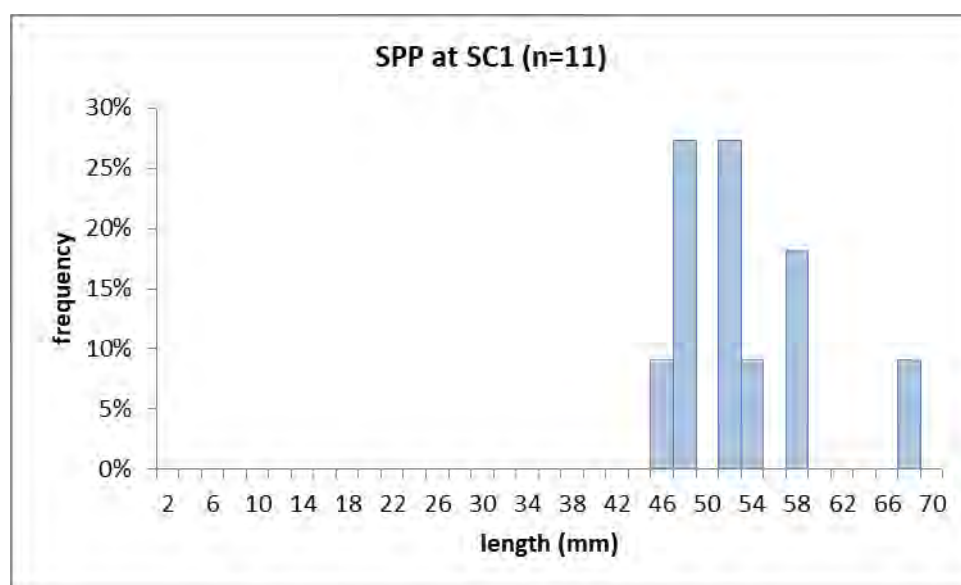


Figure 28 Length-frequency histogram of Southern Pygmy Perch at SC1.

Breakfast Creek tributary 1 (BCT1) at SV3

Plate 9 Breakfast Creek tributary (BCT1) at SV3, showing stream gauge

Breakfast Creek tributary at SV3 (relocated BCT1) consisted of a narrow, shallow stream, with a maximum width of 1.5 m. The substrate was predominantly silt/clay, with some sand, pebble and gravel present, and the lentic or pool (still) hydraulic habitats were dominant, with less than 10% glide (i.e. gentle flow) evident within the surveyed reach. The main instream cover available for fish and macroinvertebrates, in decreasing order of prevalence, consisted of coarse particulate organic matter (e.g. leaves and other organic debris), overhanging terrestrial vegetation, loose silt lying on the surface, overhanging bank, woody debris, filamentous algae, roots, and moss. The dominant aquatic vegetation type was *Blechnum* sp. The water level was slightly lower than in 2018, based on the site photographs, and stream gauge SV3 (235274A) data provided by Tom Scarborough of Barwon Water. During the sampling period in 2018, the water level ranged from 0.1–0.11 m and discharge ranged from 0.11–0.17 ML/day, whereas in 2019 the water level was 0.08–0.09 m and discharge was <0.05 ML/day.

Similarly to SC1, the macroinvertebrate results for the Breakfast Creek tributary site 1 failed to attain SEPP objectives for every index with the exception of SIGNAL2 score, of which both of the individual samples met the required score (Table 11). Whilst failing to meet all objectives, BCT1 SIGNAL2 scores were superior to those at other sites, while BCT1 EPT taxa scores were comparable to SC1. BCT1 showed slight declines against calculated macroinvertebrate indices compared with 2017 (Ecology Australia 2018), but were comparable with those from 2018 (Ecology Australia 2019). Site BCT1 has been sampled annually. The results from the past few years are fairly consistent, with some indices improving and others declining marginally.

Table 11 Individual macroinvertebrate sample indices results at BCT1, showing SEPP-W objectives (shading indicates non-attainment of SEPP objectives)

	BCT1-1	BCT1-2	BCT1-3	SEPP-W objective
# taxa	10	7		17
Abundance	48	54		-
SIGNAL2	4.7	5.3		4.2
EPT	2	4		6
EPTO	2	4		-

No Southern Pygmy Perch were detected at BCT1 during this round of monitoring. The length-frequency histogram from 2017, when the species was last detected, suggests that recruitment failure may have occurred, however detection of recruitment has been inconsistent at this site throughout the 11 years of monitoring. Southern Pygmy Perch reach maturity at approximately 30–33 mm TL (Knight 2008), and none of the fish detected in 2017 were below this threshold. However, recruitment is more reliably detected by autumn rather than spring sampling, and fish length provides only a coarse measurement of fish age/recruitment.

4 Discussion

4.1 Vegetation

Overall there appeared to be little change in vegetation health in the swamp and estuary in 2019 compared with previous years under the current MAP.

The recorded EVCs at each site did not vary from previous years in the Anglesea Swamp and Estuary (see Ecology Australia 2014–2017). Similarly, plant functional groups showed little change and continued to be dominated by aquatic and amphibious Functional Groups at every site in the Anglesea Swamp and Estuary (see Ecology Australia 2014–2017).

Total plant species numbers varied little from previous years in the swamp (Table 12) and the estuary (Table 13) and the differences are within the expected range of natural seasonal variation.

Table 12 Total plant numbers and number of plant species in Functional Groups at study sites in the Anglesea Swamp, Anglesea Borefield Monitoring and Assessment Program, 2019.

Anglesea Swamp Transect/ Site	Year	Total plant numbers	Number of plant species in Functional Group Dry (Tdr, Tda)	Number of plant species in Functional Group Amphibious (ATI, ATe, ATw; and Arp)	Number of plant species in Functional Group Aquatic (Se)
AS2	2014	13	9	2	2
	2015	13	8	2	3
	2016	15	9	2	4
	2017	16	10	2	4
	2019	15	9	4	2
AS3	2014	13	3	8	2
	2015	13	3	8	2
	2016	11	3	7	1
	2017	11	3	7	1
	2019	10	2	7	1
AS4	2014	21	9	9	3
	2015	22	9	9	4
	2016	21	8	10	3
	2017	20	8	9	3
	2019	16	4	9	3

Anglesea Swamp Transect/ Site	Year	Total plant numbers	Number of plant species in Functional Group Dry (Tdr, Tda)	Number of plant species in Functional Group Amphibious (ATI, ATe, ATw; and Arp)	Number of plant species in Functional Group Aquatic (Se)
ASP7_2014	2014	16	2	10	4
	2015	16	1	10	5
	2016	17	3	10	4
	2017	17	3	10	4
	2019	15	3	10	2
AS1_2014	2014	14	4	7	3
	2015	14	4	7	3
	2016	12	3	7	2
	2017	12	3	6	3
	2019	12	6	4	2
AGP2_2014	2014	9	2	5	2
	2015	7	2	3	2
	2016	6	1	3	2
	2017	7	1	4	2
	2019	8	1	5	2

Table 13 Total plant numbers and number of plant species in Functional Groups at study sites in the Anglesea Estuary, Anglesea Borefield Monitoring and Assessment Program, 2019.

Anglesea Estuary Transect/ Site	Year	Total plant numbers	Number of plant species in Functional Group Dry (Tdr, Tda)	Number of plant species in Functional Group Amphibious (ATI, ATe, ATw; and Arp)	Number of plant species in Functional Group Aquatic (Se)
LAR1	2015	8	3	2	3
	2017	8	3	2	3
	2019	10	3	4	3
LAR2	2015	11	4	4	3

Anglesea Estuary Transect/ Site	Year	Total plant numbers	Number of plant species in Functional Group Dry (Tdr, Tda)	Number of plant species in Functional Group Amphibious (ATI, ATe, ATw; and Arp)	Number of plant species in Functional Group Aquatic (Se)
	2017	10	4	4	2
	2019	9	3	4	2
LAR3	2015	13	6	4	3
	2017	14	7	4	3
	2019	13	7	4	2
LAR4	2015	12	3	6	3
	2017	8	2	4	2
	2019	8	3	3	2

No weed species were recorded in the swamp. Weed species continue to be recorded in the estuary (Appendix 2) in 2019. Native plant species were recorded in higher numbers and higher frequencies than weeds in 2015, 2017 and 2019 (see Ecology Australia 2015 and 2017).

The higher weed cover in the estuary likely reflects the vastly increased accessibility of the site, the disturbance history and various recreational activities that occur in and around the estuary (e.g. fishing, boating, dog walking, etc.).

Aside from vehicle tracks at one site (ASP7_2014) there appears to be little sign of disturbance in the swamp. It is recommended that vehicle access is prevented to reduce incidents and severity of future disturbance.

In the swamp, greater areas of bare ground were recorded in 2014 and 2015 compared with 2016–2019. These differences coincided with lower water levels in 2014 and 2015 (leaving exposed bare ground) and higher water levels in 2016 and 2017 (see Ecology Australia 2014–2017).

These observations are taken at one point in time and may not reflect annual average water levels or areas of bare ground so should be interpreted with caution. At present the dominance of Aquatic and Amphibious plant FGs and stable plant species numbers suggests that plants are tolerant of this variability in water levels. No bare ground was recorded in the Estuary in any years.

Algal mats continue to be recorded in the Anglesea Swamp (first recorded in 2016) (Figure 29). While algae are a normal part of wetland ecosystems, the growth of algae can also be associated with low flows (Mitrovic and Bowling 2013, Davie and Mitrovic 2014) and might suggest reduction of overbank flows in the swamp. At this stage there are no obvious impacts on the vegetation.

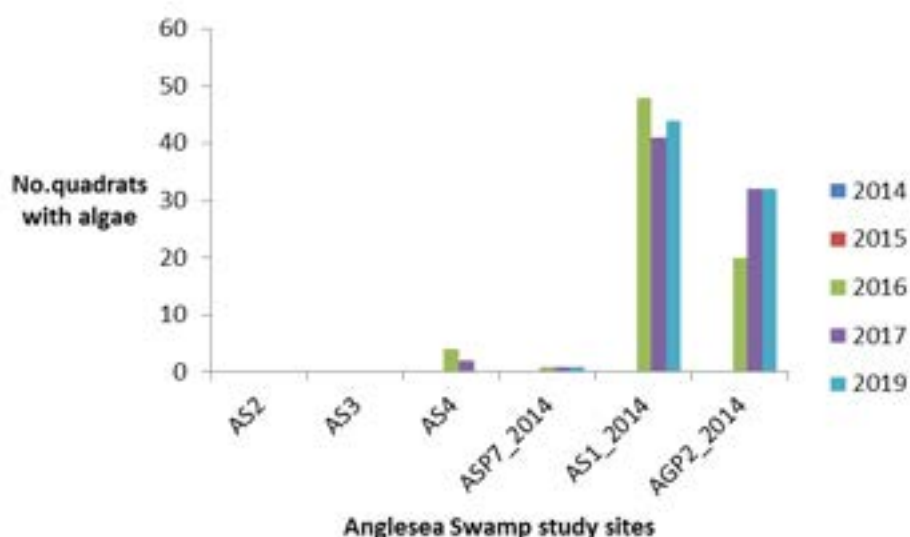


Figure 29 Algae records at study sites in the Anglesea Estuary, Anglesea Borefield Monitoring and Assessment Program, 2019

The 2019 climate data from the nearest weather station (Aireys Inlet ~ 10km away from Anglesea township) shows a mean annual rainfall of 624 mm from 1994—2019 (BOM 2020). Records indicate that the years with below average rainfall relative to the period above were 2014 (498 mm), 2015 (489 mm), 2017 (607 mm) and 2019 (525 mm). The 2016 annual rainfall (714 mm) was higher than the 1994–2019 mean (624 mm). Rainfall data was not available for 2018 (BOM 2020). The relevance of the rainfall data should be interpreted with caution given the weather station is some distance from the study sites. However, the rainfall data is useful for the purposes of demonstrating regional climatic changes which are likely to have direct influences on vegetation and algal mats.

4.2 Frogs

Results of the 2019 frog surveys as part of the Anglesea MAP are consistent with previous years, with low numbers and diversity of frogs recorded across both the Anglesea Swamp and Anglesea Estuary (Table 14, Figure 27). Although only one frog was observed at or near a survey site, frogs were heard calling at least 100 m from survey sites, indicating that frogs occur in the broader area. The low recorded diversity and abundance of frogs is likely to be correlated with the quality of frog habitat in the survey area.

The presence of water is essential for the reproduction of most Australian frog species, to allow tadpoles to mature (Hazell et al. 2003), although hydroperiod requirements will differ depending on the species' reproductive strategy. Southern Bullfrog tadpoles take up to six months to mature; hence this species needs standing water over half the year for successful reproduction (Anstis 2013). In contrast,

Common Eastern Froglet tadpoles can reach maturity in only four to six weeks, and as a result can survive in small, highly intermittent waterbodies with less stable conditions (Lane and Mahony 2002; Hazell et al. 2003; Anstis 2013). While three sites in the Anglesea Swamp supported standing water during the first frog survey, they had largely dried out by the second survey. As such, the hydroperiod at these sites may have been too short for frog reproduction during the current survey. Frogs were recorded at four of the eight sites in 2016, when winter/spring rainfall was above average (587.6 mm compared to 367.6 mm on average) and 7 of the 8 sites had standing water during the first survey (Ecology Australia 2017). Although a similar number of sites had some standing water in 2019 (5 of 8), the average water depth was lower. This may have affected frogs in several ways, including; increasing both the temperature and rate at which water evaporated, which would have further reduced the quality and/or area of frog habitat at survey sites. Taken together, these effects would have reduced options for frogs to breed and the likelihood that any eggs or tadpoles could hatch and successfully metamorphose, respectively.

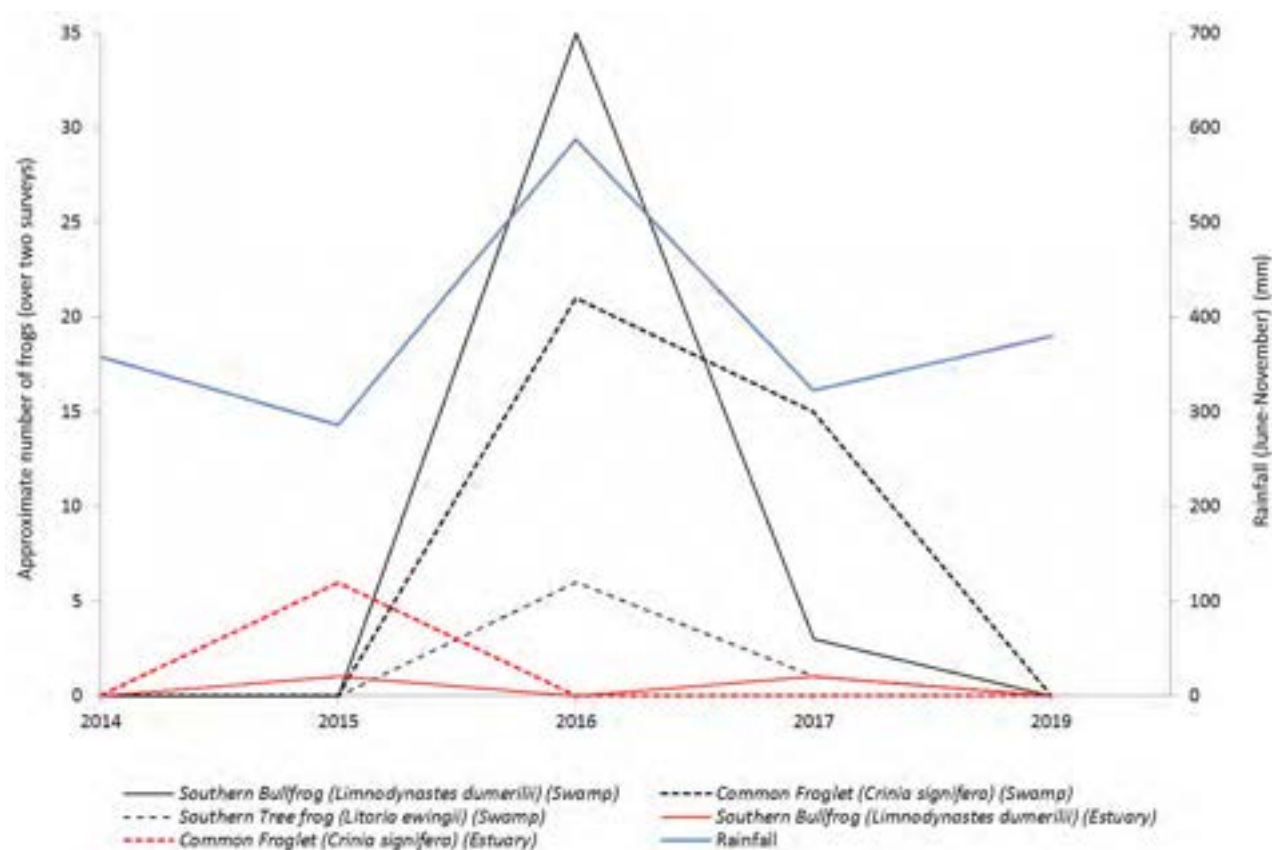


Figure 30 Approximate number of frogs recorded in spring surveys at the Anglesea Swamp and Anglesea Estuary, as part of the Anglesea Borefield Monitoring and Assessment Program, and average winter and spring rainfall, 2014–19¹. Two surveys were undertaken in each year, except for 2014, when sites were surveyed once.

¹ Rainfall data drawn from Wensleydale (station no. 87119), except for August 2014, when data were not collected at this station, and data drawn instead from Aireys Inlet (no. 90180).

Water quality metrics also influence the quality of frog habitat. Acidity can negatively impact the survival and growth of eggs and tadpoles, with 100% mortality of Striped Marsh Frog eggs below pH of 4.0 (Barth and Wilson 2010). While different species will exhibit different acidity tolerance thresholds, the very acidic conditions in those areas surveyed within the Anglesea Catchment are unlikely to be conducive to frog reproduction. However, whether this is a long-term situation is impossible to answer in the absence of long-term data.

High levels of salinity can also have a negative impact on frog populations. The survival of Southern Brown Tree Frogs is reduced in saline conditions (Chinathamby et al. 2006), and fewer Southern Bullfrogs have been recorded in stormwater ponds with elevated salinity (Hamer et al. 2012). Moderately high salinity/electrical conductivity levels were recorded at both the Swamp (1.44–4.54 ms/cm) and Estuary (4.81–14.5 ms/cm), which may further reduce the potential for frogs to reproduce in these areas.

Table 14 Number of survey sites in the Anglesea Swamp and Anglesea Estuary at which frogs were recorded during spring surveys of the Anglesea MAP, 2014–19.

Area	Common name	Species	2014	2015	2016	2017	2019
Anglesea Swamp	Southern Tree Frog	<i>Litoria ewingii</i>	0	0	2	1	0
	Southern Bullfrog	<i>Limnodynastes dumerilii</i>	0	0	2	1	0
	Common Froglet	<i>Crinia signifera</i>	0	0	3	1	0
		Any species	0	0	4	1	0
Anglesea Estuary	Southern Tree Frog	<i>Litoria ewingii</i>	NA	0	NA	0	0
	Southern Bullfrog	<i>Limnodynastes dumerilii</i>	NA	1	NA	1	0
	Common Froglet	<i>Crinia signifera</i>	NA	2	NA	0	0
		Any species	NA	3	NA	1	0

4.3 Aquatic Ecology

The macroinvertebrate survey results were relatively consistent with previous years, with sites demonstrating slight improvements for some indices, and minor reductions in others. The low abundance and diversity of macroinvertebrates detected, and poor performance against SEPP objectives could be attributed to a few different factors. Due to the limited surface water present at all sites, all, or nearly all available surface water was sampled at every suitable site. This is likely to impact upon the results, as this reduces the degree of selectiveness that can be employed in sampling all microhabitats present; and it is possible that some sites may not have been wetted for a sufficient period for colonisation/re-colonisation by the full complement of potential species. Additionally, the reduction in connectivity between sites influences colonisation, and is further influenced by the motility of each taxa. The impacts of acid sulphate soils and/or acid events can result in low pH levels, most notably in Wetland 2/3. Reductions in surface water as a result of evaporation and evapotranspiration further reduce the suitability for macroinvertebrates and other aquatic life, as physicochemical parameters (such as salinity and temperature) become more extreme; as is potentially demonstrated by the high electrical conductivity noted at site W2/3.

The Southern Pygmy Perch population in the Anglesea catchment was identified as genetically distinct from surrounding catchments, and at the time of genetic assessment, the historically abundant populations from the Anglesea River and surrounding wetlands were not detected (Cesar 2012). If further surveys of Southern Pygmy Perch in the broader catchment area were to be undertaken and yield similar results to that found previously (Cesar 2012), then the populations present in Salt Creek and Breakfast Creek tributary may be important source populations for recolonisation lower in the catchment. Southern Pygmy Perch has not been detected at BCT1 since 2017, however the population at BCT1 has previously persisted despite three successive spring sampling events where no recruits were detected (2012–14) (GHD 2013–2015). Appearance and reappearance at BCT1 may indicate that the site does not encompass the local Breakfast Creek source population. In Salt Creek, the population appears to have had successful annual recruitment at SC1 with the exception of 2019. It should be noted that as a species that breeds predominantly in spring, the timing of sampling (spring) hampers the reliability of recruitment detection. While the review of the MAP (GHD 2013b) suggested the BCT1 population was relatively stable, the more recent surveys have detected many more individuals and much more consistent evidence of recruitment at SC1.

The most notable result from the aquatic ecological monitoring in recent years was the detection of the endangered Otway Bush Yabby. This species has previously been recorded in Salt Creek in 2007 (Schultz 2007), however 2017 was the first time it was recorded as part of this monitoring program. Based on the abundance and size ranges encountered, the population appears to be stable.

Recommendations in regards to the aquatic monitoring were proposed after the 2018 monitoring event (Ecology Australia 2019). These recommendations remain current and are reproduced and expanded upon below:

- Due to the limited presence of surface water, it may be beneficial to reduce the number of macroinvertebrate samples per site from three down to two, to avoid oversampling which likely results in poorer results per sample. As the new SEPP-W indices for macroinvertebrates are based on single samples, there is a greater importance in collecting higher quality individual samples. The trade-offs of this approach in terms of reduced replication and reduced data compatibility also require consideration. This change would best be considered as part of a review of the MAP.
- Given the recent failure to detect Southern Pygmy Perch at BCT1, it would be beneficial to reassess the catchment for additional populations. This has not been done since 2012, and would ideally focus on historic records from Anglesea River and associated wetlands and Breakfast Creek in addition to known refuge pools throughout Salt Creek and Anglesea River (as identified in GHD 2010), and an investigation into refuge pools in the Breakfast Creek catchment. As a genetically distinct population in an isolated catchment, it is of concern that the species may have retracted to a single remnant population. This results in a high level of vulnerability for this genetic lineage. This assessment can be undertaken at any time, but would ideally be undertaken in late summer/autumn.
- Consideration should be given to the inclusion of Otway bush yabby in the monitoring program in future years, including investigations into the extent of the population throughout the study area. The inclusion of this species as a target of the monitoring program was undertaken in 2019. This required no modification to the methods other than collecting biometric data from the specimens collected. Investigating the extent of the population

distribution can be undertaken at any time, but would ideally be undertaken in late summer/autumn, and would most cost effectively be undertaken in conjunction with the catchment-based investigation into detecting additional Southern Pygmy Perch populations.

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Appendix 1 Anglesea Borefield, terrestrial ecology, Monitoring and Assessment Program,
Anglesea Swamp, native plant species and Functional Groups (native plant species
only) spring 2019

Status	Scientific name	Common name	Functional group	AS2	AS3	AS4	ASP7_2014	AS1_2014	AGP2_2014
	<i>Banksia marginata</i>	Silver Banksia	Tdr	✓		✓		☐	
	<i>Baumea arthropophylla</i>	Fine Twig-sedge	Se	☐		✓	✓		✓
	<i>Baumea juncea</i>	Bare Twig-sedge	Tda			☐	✓	✓	
	<i>Baumea tetragona</i>	Square Twig-sedge	Se	✓	✓	✓		☐	
	<i>Cassytha glabella</i>	Slender Dodder-laurel	Tdr	☐	✓	✓	✓	✓	
	<i>Cassytha pubescens</i>	Downy Dodder-laurel	Tdr	✓		☐	☐	☐	
	<i>Cynnogeton alcockiae</i>	Southern Water-ribbons	Se	✓		✓	✓	✓	✓
	<i>Eleocharis sphacelata</i>	Tall Spike-sedge	Se	☐				✓	
	<i>Empodisma minus</i>	Spreading Rope-rush	ATe	☐	✓	✓	✓	✓	✓
	<i>Epacris obtusifolia</i>	Blunt leaf-Heath	ATw		✓	✓	✓	☐	
	<i>Eucalyptus falciformis</i>	Western Peppermint	Tdr	✓	☐				
	<i>Gahnia radula</i>	Thatch Saw-sedge	Tdr	✓				✓	
	<i>Gahnia sieberiana</i>	Red-fruit Saw-sedge	ATe	✓	☐	✓	✓		✓
	<i>Gleichenia dicarpa</i>	Pouched Coral-fern	ATe	☐	✓	✓	✓	✓	
	<i>Gleichenia microphylla</i>	Scrambling Coral-fern	ATe			✓		☐	
	<i>Juncus procerus</i>	Tall Rush	ATe	✓		☐	☐		✓
	<i>Lepidosperma longitudinale</i>	Pithy Sword-sedge	ATe	☐	☐	✓	✓		✓
	<i>Leptospermum continentale</i>	Prickly Tea-tree	Tdr		✓	✓	✓	✓	
	<i>Leptospermum lanigerum</i>	Woolly Tea-tree	ATw				✓		
	<i>Leptospermum scoparium</i>	Manuka	Tda	✓		✓		✓	✓
	<i>Melaleuca squarrosa</i>	Scented Paperbark	ATw	✓	✓	✓	✓	✓	✓
	<i>Opercularia varia</i>	Variable Stinkweed	Tdr	✓		☐	☐		☐
	<i>Platylobium obtusangulum</i>	Common Flat-pea	Tdr	✓		☐			
	<i>Pteridium esculentum</i>	Bracken	Tdr	✓	☐		☐	✓	☐
	<i>Rhytidosporum</i>	White Marianth	Tdr	✓	☐	☐	☐	☐	☐

Status	Scientific name	Common name	Functional group	AS2	AS3	AS4	ASP7_2014	AS1_2014	AGP2_2014
	<i>procumbens</i>								
	<i>Schoenus brevifolius</i>	Zig-zag Bog-sedge	ATe	✓	✓	✓	✓	✓	
	<i>Sprengalia incarnata</i>	Pink Swamp-heath	ATw		✓	✓	✓	□	
	<i>Xyris operculata</i>	Tall Yellow-eye	ATe		✓		✓	□	

Appendix 2 Anglesea Borefield, terrestrial ecology, Monitoring and Assessment Program, Anglesea Estuary, plant species and Functional Groups (native plant species only) spring 2019

Key:

= Victorian species not indigenous to the region, location or local area

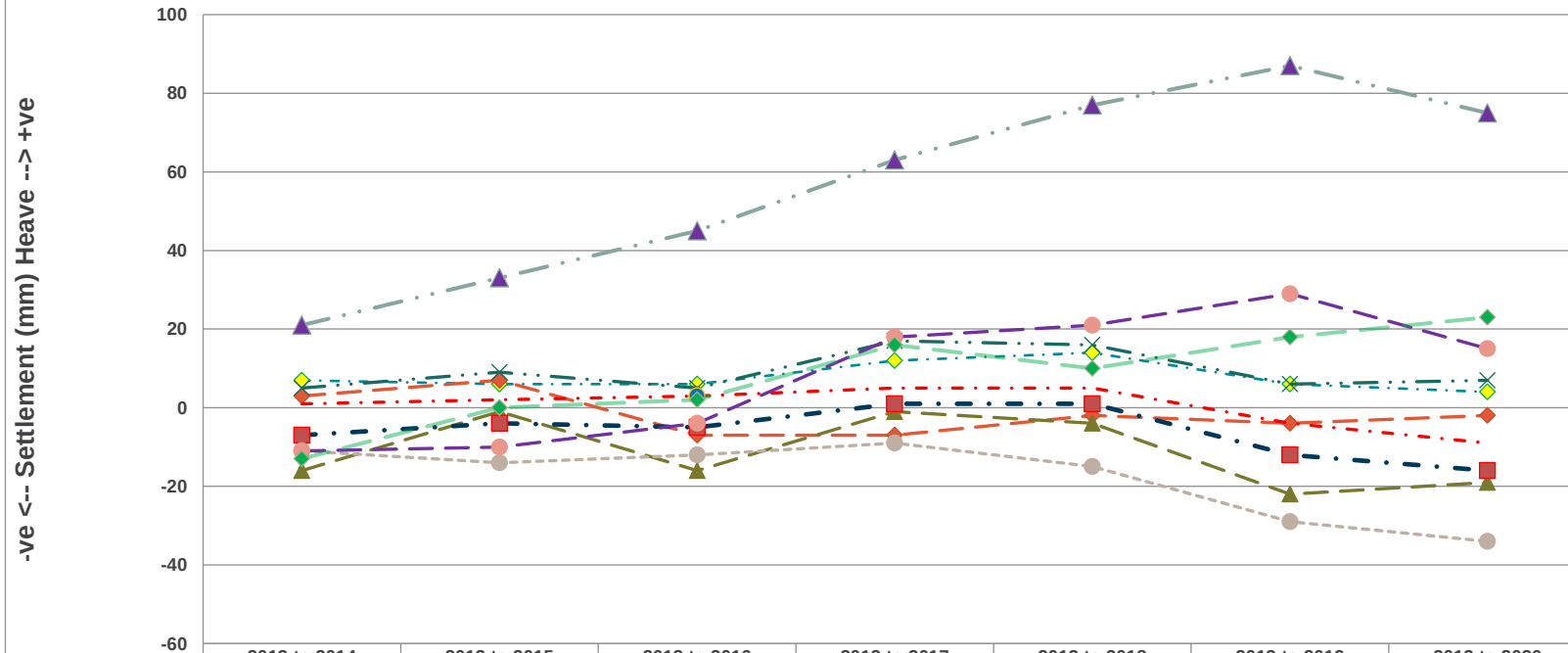
* = Species not native to Victoria

Status	Scientific name	Common name	Functional group	LAR1	LAR2	LAR3	LA R4
#	<i>Acacia longifolia</i> subsp. <i>longifolia</i>	Sallow Wattle	NA			✓	
#	<i>Acacia longifolia</i> subsp. <i>sophorae</i>	Coast Wattle	NA	✓			
*	<i>Aira elegantissima</i>	Delicate Hair-grass	NA			✓	
	<i>Cycnogeton procerum</i> sp. aff.	Common Water-ribbons	Se	✓	✓	✓	✓
	<i>Eucalyptus ovata</i> . var. <i>ovata</i>	Swamp Gum	Tda	✓		✓	
	<i>Ficinia nodosa</i>	Knobby Club-sedge	Tdr			✓	✓
	<i>Gahnia sieberiana</i>	Red-fruit Saw-sedge	Ate	✓			
	<i>Goodenia ovata</i>	Hop Goodenia	Tdr	✓		✓	✓
	<i>Juncus kraussii</i> ssp. <i>australiensis</i>	Sea Rush	Se	✓	✓	✓	✓
	<i>Leptinella longipes</i>	Coast Cotula	ARp		✓	✓	✓
	<i>Leptospermum continentale</i>	Prickly Tea-tree	Tdr			✓	
	<i>Leptospermum scoparium</i>	Manuka	Tda	✓	✓	✓	
	<i>Lobelia anceps</i>	Angled Lobelia	ATe	✓	✓	✓	✓
	<i>Myoporum insulare</i>	Common Boobialla	Tda		✓		
	<i>Phragmites australis</i>	Common Reed	ARp	✓	✓	✓	
	<i>Poa poiformis</i> var. <i>poiformis</i>	Coast Tussock-grass	Tdr		✓	✓	✓
	<i>Selliera radicans</i>	Shiny Swamp-mat	ARp	✓	✓	✓	✓
	<i>Senecio glomeratus</i> s.l.	Annual Fireweed	Tdr			✓	
*	<i>Symphotrichum subulatum</i>	Aster-weed	NA		✓		✓
	<i>Typha domingensis</i>	Narrow-leaf Cumbungi	Se	✓			
*	<i>Vulpia</i> sp.	Fescue	NA		✓		

Appendix 3 Results by sample of macroinvertebrate sampling

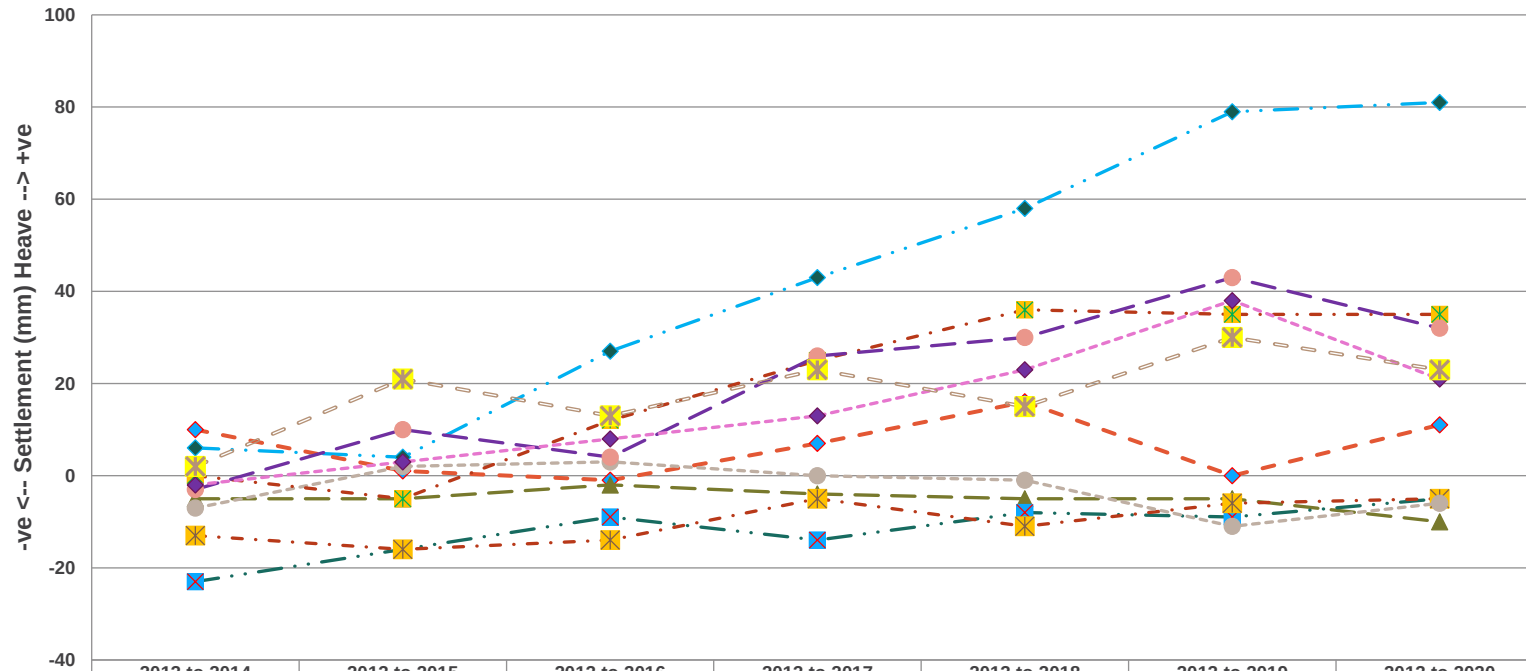
Taxa	BC T1 E1	BC T1 E2	BCT 1 Total	SC1 E1	SC1 E2	SC1 E3	SC1 Total	W2 /3 E1	W2 /3 E2	W2 /3 E3	W2 /3 Total	Total
Acarina	6		6	4	2	6	12					18
Carabidae (adult)				1			1					1
Ceratopogonidae									2		2	2
Chironominae				2		3	5					5
Crambidae		1	1									1
Culicidae	8		8			30	30	63		26	89	127
Curculionidae (adult)								1	1		2	2
Dytiscidae (adult)				1	8	9	18	1	2	1	4	22
Dytiscidae (larvae)		1	1	5		13	18					19
Gripopterygidae <i>Dinatoperla/Leptoperla</i>				6			6					6
Gripopterygidae <i>Leptoperla</i>		4	4									4
Gyrinidae (adult)								1			1	1
Hydraenidae (adult)						2	2		1		1	3
Hydrobiosidae <i>Taschorema</i> complex				1			1					1
Hydrochidae (adult)						1	1					1
Hydrophilidae (adult)				1		2	3		7		7	10
Janiridae	1		1									1
Koonungidae					2	4	6					6
Leptoceridae <i>Triplectides</i>	13	2	15									15
Leptophlebiidae (a mix of damaged and immature specimens)				3			3					3
Leptophlebiidae <i>Nousia</i>		2	2									2
Leptophlebiidae <i>Thraulophlebia</i>	7	8	15	29	1	18	48					63
Oligochaeta	2		2	7			7			1	1	10
Orthoclaadiinae	2		2	5		5	10					12
Paramelitidae				17		6	23					23
Parastacidae <i>Geocharax</i> <i>tasmanicus</i>	4	33	37	1	1	1	3					40
Polycentropodidae <i>Plectrocnemia</i>	1	3	4	4			4					8
Scirtidae (larvae)	4		4	1	7	1	8	15	25	27	67	79
Veliidae					1	12	13					13
Total	48	54	102	88	22	113	223	81	38	55	174	499

2020 Anglesea borefield land level surveying
Monitoring Marks ALS 1- 10
 (Change in level (mm) compared to the 2013 set of readings)



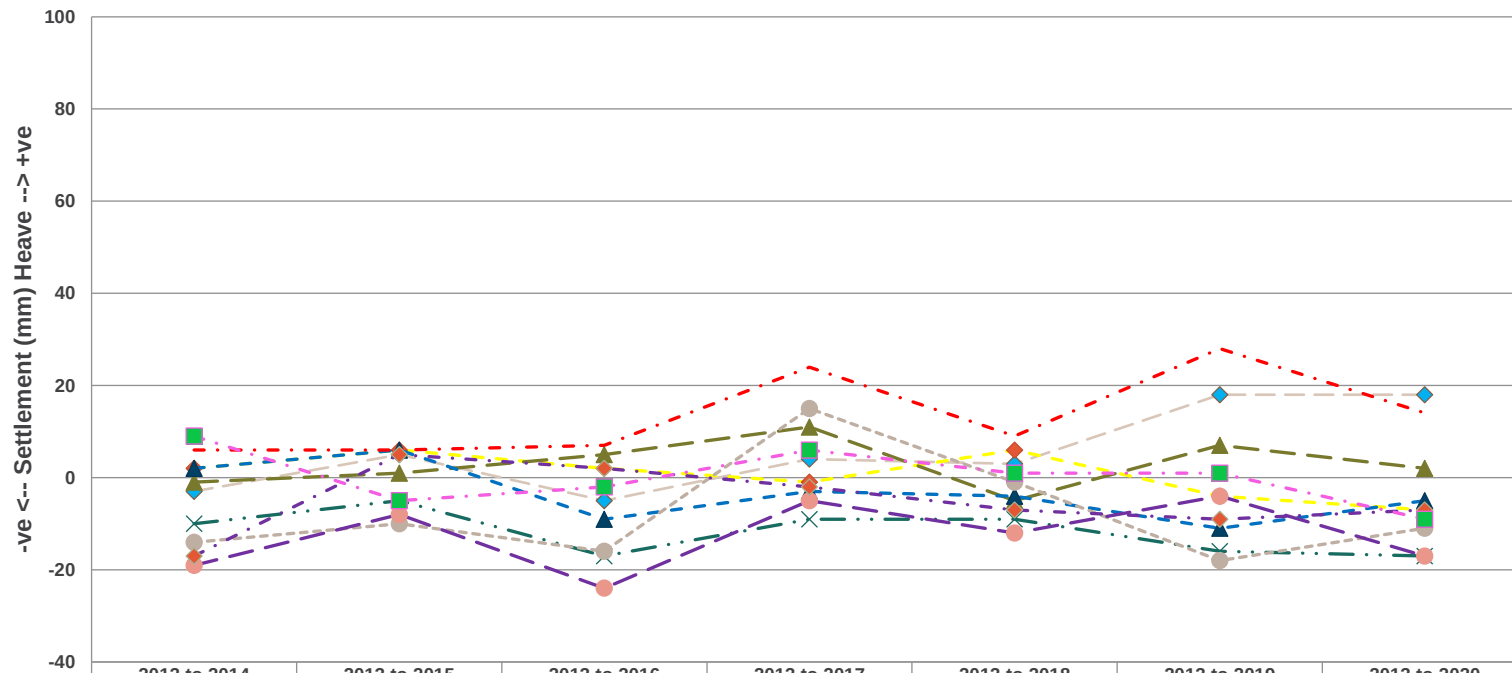
	2013 to 2014	2013 to 2015	2013 to 2016	2013 to 2017	2013 to 2018	2013 to 2019	2013 to 2020
ALS 1	7	6	6	12	14	6	4
ALS 2	3	7	-7	-7	-2	-4	-2
ALS 3	-16	-1	-16	-1	-4	-22	-19
ALS 4	5	9	5	17	16	6	7
ALS 5	-7	-4	-5	1	1	-12	-16
ALS 6	-11	-14	-12	-9	-15	-29	-34
ALS 7	1	2	3	5	5	-4	-9
ALS 8	-11	-10	-4	18	21	29	15
ALS 9	-13	0	2	16	10	18	23
ALS 10	21	33	45	63	77	87	75

2020 Anglesea borefield land level surveying
Monitoring Marks ALS 11- 20
(Change in level (mm) compared to the 2013 set of readings)



	2013 to 2014	2013 to 2015	2013 to 2016	2013 to 2017	2013 to 2018	2013 to 2019	2013 to 2020
ALS 11	6	4	27	43	58	79	81
ALS 12	10	1	-1	7	16	0	11
ALS 13	-5	-5	-2	-4	-5	-5	-10
ALS 14	-23	-16	-9	-14	-8	-9	-5
ALS 15	-13	-16	-14	-5	-11	-6	-5
ALS 16	-7	2	3	0	-1	-11	-6
ALS 17	0	-5	12	25	36	35	35
ALS 18	-3	10	4	26	30	43	32
ALS 19	-2	3	8	13	23	38	21
ALS 20	2	21	13	23	15	30	23

2020 Anglesea borefield land level surveying
Monitoring Marks ALS 21- 30
 (Change in level (mm) compared to the 2013 set of readings)



	2013 to 2014	2013 to 2015	2013 to 2016	2013 to 2017	2013 to 2018	2013 to 2019	2013 to 2020
ALS 21	-3	5	-5	4	3	18	18
ALS 22	2	6	2	-1	6	-4	-7
ALS 23	-1	1	5	11	-5	7	2
ALS 24	-10	-5	-17	-9	-9	-16	-17
ALS 25	2	6	-9	-3	-4	-11	-5
ALS 26	-14	-10	-16	15	-1	-18	-11
ALS 27	6	6	7	24	9	28	14
ALS 28	-19	-8	-24	-5	-12	-4	-17
ALS 29	-17	5	2	-2	-7	-9	-7
ALS 30	9	-5	-2	6	1	1	-9



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Anglesea Borefield MAP - Aquatic Ecological Monitoring 2018



Prepared for: Barwon Water

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Cover photo: Otway bush yabby *Geocharax gracilis* captured at site BC2

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Ethics and Permits

All surveys were undertaken under the following ethics and research permits granted to Ecology Australia:

- Wildlife and Small Institutions Animal Ethics Committee (WSIAEC) projects 11.16;
- Fisheries Research Permit 1142;
- *Wildlife Act 1975, Flora and Fauna Guarantee Act 1988, and National Parks Act 1975* Research Permit 10007806; and
- Scientific Procedures Fieldwork Licence 20097.

Summary

Ecology Australia was commissioned by Barwon Water to conduct the spring 2018 ecological Monitoring and Assessment Program (MAP) for the Anglesea Borefield Project (ABP). This consisted of the aquatic ecological (fish and macroinvertebrates) components of the revised MAP (Victorian Government 2014).

The aquatic monitoring component of the revised MAP is required annually at three sites, and triennially at 11 sites. Triennial monitoring of all 11 sites was last completed in 2015, and hence was conducted again in 2018. Monitoring consists of modified RBA sampling for macroinvertebrates at all sites, and targeted sampling for a genetically distinct population of Southern Pygmy Perch *Nannoperca australis* using bait traps.

All macroinvertebrate samples exhibited low abundance and diversity, which is consistent with previous years. No samples met the SEPP objectives for number of taxa, key families, or number of EPT taxa. Some samples and/or overall sites met the objectives for SIGNAL scores. Limited availability of surface water including poor connectivity, and poor water quality are likely to be contributing factors in the poor macroinvertebrate indices results.

A total of 56 Southern pygmy perch were captured from Salt Creek (SC1), and none were captured from Breakfast Creek tributary (BCT1). The abundance of Southern pygmy perch in SC1 appears to have been highly variable over the 11 years of monitoring, but catch per unit effort appears to have stabilised after a potential population reduction in 2016. Recruitment appears to have occurred annually at SC1. Recruitment has not been detected at BCT1 since spring 2016. The populations in Salt Creek and Breakfast Creek tributary may be important source populations for recolonisation lower in the catchment.

Otway bush yabby *Geocharax gracilis* was detected at six of the eleven surveys locations, including repeat detections at the two study sites where they were detected in 2017 (Ecology Australia 2018), and four new sites. A total of 126 individuals were detected. Otway bush yabby is listed as Endangered on the Victorian Advisory List of threatened invertebrates (DSE 2009).

Due to the limited presence of surface water, it may be beneficial to reduce the number of macroinvertebrate samples per site from three down to two, to avoid oversampling sites that consist of small refuge pools; oversampling likely results in poorer results per sample.

Given the recent failure to detect Southern pygmy perch at BCT1, it would be beneficial to reassess the catchment for additional populations. As a genetically distinct population in an isolated catchment, it is of concern that the species may have retracted to a single remnant population as this would indicate a high level of vulnerability for this genetic lineage.

Consideration should be given to formalised inclusion of Otway bush yabby in the monitoring program in future years, including investigations into the extent of the population throughout the study area.

1 Introduction

Ecology Australia was commissioned by Barwon Water to conduct the spring 2018 ecological Monitoring and Assessment Program (MAP) for the Anglesea Borefield Project (ABP). This consisted of the aquatic ecological (fish and macroinvertebrates) components of the revised MAP (Victorian Government 2014).

The ABP was established to access and supply ground water to Geelong and surrounding areas in periods of drought when demands placed on regular water supply sources exceed capacity.

The MAP is a requirement of the ABP under the Bulk Entitlement (BE) (Anglesea Groundwater) Order 2009, established under the Water Act 1989. It was developed and implemented in 2009 (Victorian Government 2009) to assess the impacts of water draw down on the environment and the long term sustainability of the program. Potential risks to ecological values include acid generation, reduced water table (aquifer levels) and altered surface water regime.

Ecology Australia has developed and conducted the terrestrial monitoring components to date, the details of which are provided in annual reports (Ecology Australia 2009–2013a). GHD undertook the initial aquatic ecology monitoring program (GHD 2010–2017). This is the second year that Ecology Australia has undertaken the aquatic ecology monitoring components of the program.

As required under the BE (Victorian Government 2009), a review of the MAP was carried out in 2013 and knowledge gaps were addressed (GHD 2013b, Ecology Australia 2013b). The outcome was a revised focus with terrestrial monitoring targeting specific areas identified as currently at risk, which include the Anglesea Swamp and the Anglesea Estuary. The survey protocol for aquatic monitoring under the revised MAP (Victorian Government 2014) requires:

- Annual spring monitoring of macroinvertebrates at three sites:
 - Breakfast Creek tributary (BCT1);
 - Salt Creek (SC1); and
 - Lower Anglesea River wetland (Wetland 3).
- Annual spring sampling of Southern pygmy perch *Nannoperca australis* at two sites:
 - Breakfast Creek tributary (BCT1); and
 - Salt Creek (SC1).
- Triennial spring sampling of macroinvertebrates at all 11 aquatic monitoring sites.

Triennial monitoring of all 11 sites was last completed in 2015, and hence was conducted again in 2018.

The terrestrial ecology component of the revised MAP included baseline monitoring of the Anglesea Swamp for three consecutive years (2014–2016) which is now complete (Ecology Australia 2014, 2015 & 2016). From 2017 onwards, the current MAP requires the swamp to be monitored biennially in the absence of ground water pumping, and annually during water draw down.

The estuary was last monitored in 2015 (Ecology Australia) and in the continued absence of ground water pumping, was monitored again in 2017 (Ecology Australia 2018).

To align with the Anglesea Estuary monitoring, at the request of Barwon Water, biennial monitoring of the Anglesea Swamp commenced in 2017. As a result, no terrestrial monitoring was required in 2018.

2 Study Area

The study area encompasses the Anglesea Swamp, located within Anglesea Heath Park, Otway Forest Park and Great Otway National Park. Eleven sites were investigated for the 2018 monitoring program and are listed in Table 1 and depicted in Figure 1.

Table 1 List of sites investigated in 2018 including location and sampling regime

Site name	Site ID	Easting	Northing	Sampling required
Upper Anglesea River 1	UAR1	242968	5752428	Macroinvertebrate sampling
Upper Anglesea River 2	UAR2	246596	5753550	Macroinvertebrate sampling
Breakfast Creek 1	BC1	240936	5746555	Macroinvertebrate sampling
Breakfast Creek 2	BC2	243188	5747870	Macroinvertebrate sampling
Breakfast Creek 3	BC3	243466	5747638	Macroinvertebrate sampling
Breakfast Creek Tributary 1	BCT1*	242894	5748151	Macroinvertebrate and fish sampling
Breakfast Creek Tributary 2	BCT2	242917	5748114	Macroinvertebrate sampling
Salt Creek (above swamplands)	SC1	245272	5746978	Macroinvertebrate and fish sampling
Anglesea Wetland 1	Wetland 1	252545	5748828	Macroinvertebrate sampling
Anglesea Wetland 2	Wetland 2	253277	5747834	Macroinvertebrate sampling
Anglesea Wetland 3	Wetland 3	253304	5747866	Macroinvertebrate sampling

GDA94 Map Zone 55H

*moved to SV3 for consistency with previous years (refer to section 3.1)

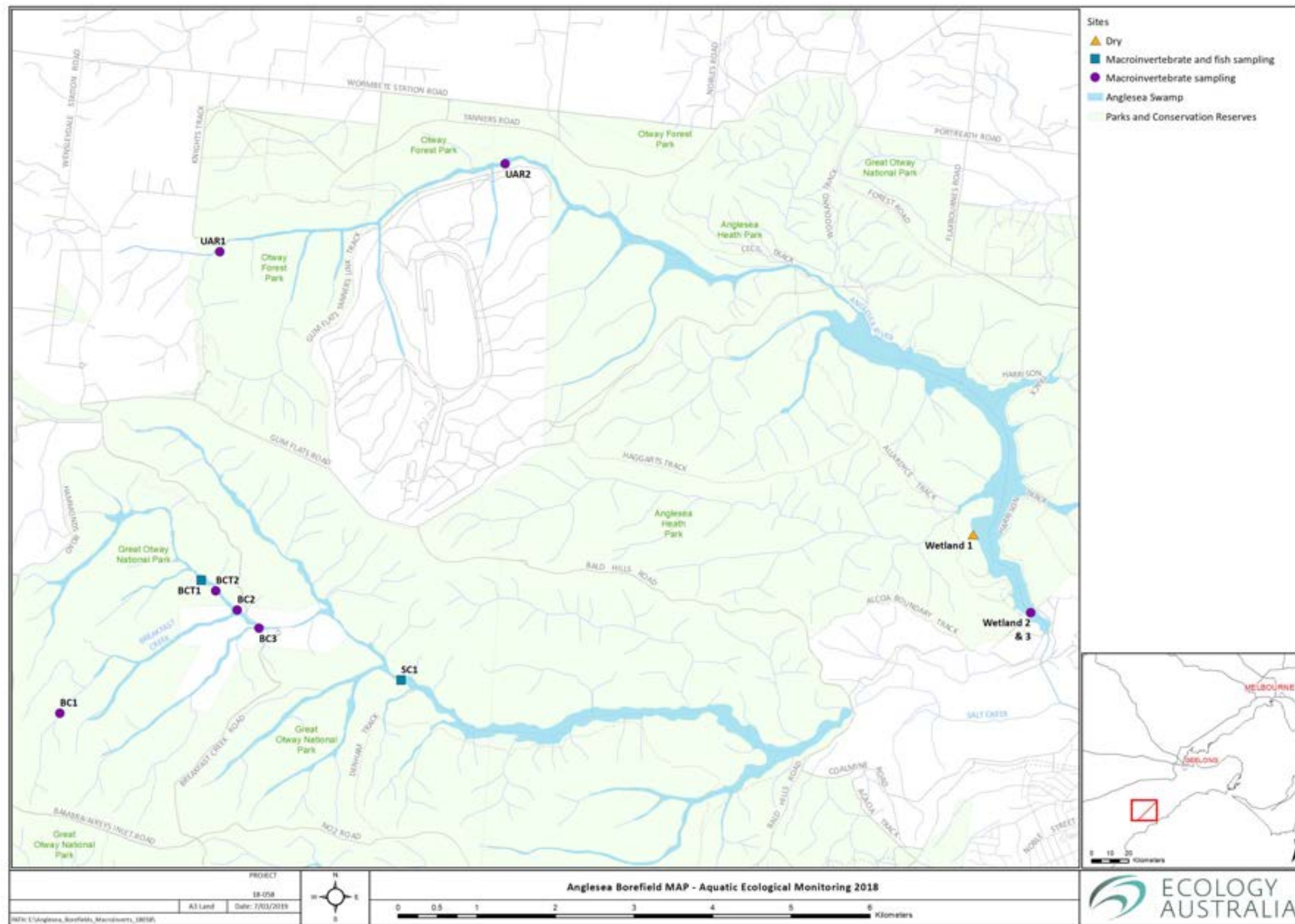


Figure 1 The locations of the eleven sites investigated in 2018

3 Methods

The aquatic sampling methods used are based on the revised MAP requirements and approaches used by GHD (2010–2017), with minor modifications as per the methods carried out by Ecology Australia in spring 2017 (Ecology Australia 2018).

Under the revised MAP (Victorian Government 2014) terrestrial ecological (vegetation and frog) monitoring was not undertaken in 2018 and spring aquatic ecological monitoring was conducted as required at all suitable sites (Figure 1).

3.1 Macroinvertebrate surveys

Macroinvertebrate surveys were undertaken at nine sites on 16–19 October 2018. Site BCT1 was again relocated downstream due to insufficient surface water being present at or within the vicinity of the location coordinates provided in 2017. Based on photographs of BCT1 by GHD (2016), it was apparent that the site has previously been relocated to stream gauge SV3 (Ecology Australia 2018). Following consultation with Mark Dodgshun of Barwon Water, the survey was again undertaken at SV3, however for consistency it will be referred to as BCT1. Wetland 1 could not be sampled as there was insufficient surface water available to collect three samples. Wetland 2 and Wetland 3 were combined into a single site, as they act as a single waterbody due to connectivity between the two sites, and as there was insufficient water in either one to collect three samples, but sufficient water once the two sites were combined.

As per the methods outlined by GHD (2016), triplicate edge samples were collected at each site following the methods outlined in the Victorian Rapid Bioassessment (RBA) Methodology for Rivers and Streams (EPA 2003). A 0.25 mm mesh net with a 30 cm x 30 cm opening was used to collect each sample. Edge ('sweep') samples were collected from water bodies with little to no flow. The sampling objective was to subsample all types of habitats present, which can include overhanging vegetation, coarse woody debris, backwaters, bare edges, leaf packs and macrophytes. Each sample consisted of 10 m of habitat, which was not necessarily contiguous. The water and habitat was agitated to dislodge macroinvertebrates and suspend them within the water column. Additional invertebrates which were observed but not collected (e.g. fast moving) were noted on the sample label.

Samples were live-sorted ('picked') following the standard RBA procedures and preserved in 70% ethanol. In summary, the procedures entail:

- Picking for 30 minutes from a white tray, aiming to collect 200 animals from as many different taxa as possible;
- If less than 200 animals are collected within 30 minutes then picking continues for an additional 10 minutes;
- If 200 animals are collected within 40 minutes and no new taxa are detected, then picking ceases; otherwise picking continues for an additional 10 minutes. This continues until a maximum of 60 minutes of picking has been completed; and
- Avoidance of favouring large and abundant taxa over smaller, more cryptic taxa, by picking a maximum of approximately 30 of each taxa, with the exception of animals which may superficially appear to be the same but typically require microscopic examination to identify the additional taxa (e.g. Chironomid subfamilies).

At each site, RBA field sampling and habitat assessment sheets were completed, including in situ water quality measurements using a calibrated U-52 Horiba water quality meter.

3.1.1 Macroinvertebrate identification

Macroinvertebrates were identified and enumerated with a stereo microscope using keys outlined in MDFRC (2013), which provides an update on those outlined in Hawking (2000). The majority of taxa were identified to family level with the following exceptions as per the RBA protocols (EPA 2003):

- Chironomidae are identified to sub-family;
- Oligochaeta and Acarina are not identified below these taxonomic levels;
- Adult and larval beetles are listed separately; and
- Taxa excluded from the recommended indices were discarded.

Additionally, specimens of the orders Ephemeroptera, Plecoptera, Trichoptera and Odonata were identified to genus level, as per GHD (2015–2017).

3.2 Macroinvertebrate data analyses

Macroinvertebrate data were analysed both as individual samples, and on a site basis using the combined data from three samples. Where available, the results were compared against indices in State Environment Protection Policy – Waters of Victoria (SEPP-WoV) (2003). SEPP-WoV objectives are based on combined edge and riffle samples, so these are provided as a guideline only as the current sampling regime consists of triplicate edge samples. The SEPP has been updated since the last year of monitoring and is now SEPP-W (Victorian Government Gazette 2018). SEPP-WoV indices have been used for consistency with previous reports (GHD 2010-2017, Ecology Australia 2018), in addition to SEPP-W objectives to be in line with current indices.

The following indices were used to analyse macroinvertebrate data:

- Number of taxa — total number of taxa based on taxonomic resolution levels described in Section 3.1.1;
- Abundance — total number of individuals collected excluding those that were discarded (e.g. Collembolla, Staphlinidae beetles);
- Number of EPA key families — based on the number of taxa that have been identified as typical of waterways in this region (segment B3: Forests B) (Victorian Government Gazette 2003);
- SIGNAL score — average SIGNAL score for taxa collected in each sample, using the scores adopted by EPA (2003) and based on methods of Chessman (1995). Table 2 provides the corresponding water quality categories;
- Number of EPT taxa — number of taxa from the orders of Ephemeroptera, Plecoptera and Trichoptera (EPT), which are considered more sensitive to pollution and disturbance and hence are considered an indicator of ecosystem health;
- Number of EPTO taxa — number of taxa from the orders of Ephemeroptera, Plecoptera, Trichoptera and Odonata (EPTO). This index is used for waterways in 'Mediterranean climate' regions, and aids in interpreting the health of lentic (still water) systems, where the numbers

of Plecoptera are diminished while Odonata, which are also relatively sensitive to pollutants and disturbance, are more abundant and diverse (Pinto et al. 2004)

Table 2 SIGNAL score classifications

SIGNAL score	Water quality
>7	Excellent
6-7	Clean water
5-6	Mild pollution
4-5	Moderate pollution
<4	Severe pollution

3.3 Fish surveys

Surveys targeting Southern pygmy perch *Nannoperca australis* were undertaken at two sites; SC1 and BCT1 on 17–19 October 2018. As with the macroinvertebrate surveys, site BCT1 was relocated downstream due to insufficient surface water (see 3.1).

Ten bait traps (mesh size of 2 mm and funnel entrances of 4 cm) with 4 inch yellow glow sticks were set in the afternoon and retrieved the following morning at both sites. This is a modification of the methods used by GHD (2015–2017), where it is believed that five bait traps were set each year during surveys conducted from 2012–2016 (GHD 2013–2017). The number of traps was increased to increase the likelihood of collecting 30 Southern pygmy perch per site.

The first 30 Southern pygmy perch were required to be measured (total length) to the nearest millimetre, and weighed to the nearest 0.1 gram. Subsequent Southern pygmy perch were also measured to increase the accuracy of population structure estimates. Additional taxa of interest detected in bait traps or observed at each site were recorded, with a particular focus on threatened crayfish Otway bush yabby *Geocharax gracilis*.

Instream habitat assessment was undertaken at all sites surveyed. The habitat assessment included notes on existing sources of disturbance, notes and estimates of biological and physical attributes (e.g. wetted instream cover, riparian shading, aquatic vegetation, substrate composition, flow and depth) and in situ water quality measurement. An outline of some of these habitat descriptors is provided below:

- The percentage cover of various forms of instream habitat (based on the proportion of the wetted area that they covered at the time of assessment).
- The shading estimate as per the EPA Rapid Bioassessment method (EPA 2003). This is an estimate based on a plan view as it would appear with the sun directly overhead (i.e. midday).
- The flow status estimate is as per the USEPA fieldsheets that are incorporated into the latest iteration of the Victorian EPA Rapid Bioassessment fieldsheets (Version: September 2012). This is an estimate based on the proportion of the channel filled and/or substrate exposed.
- The disturbance rating estimate is based on identification of a number of disturbance sources including levels of bank erosion, riparian vegetation clearance, parallel or adjacent roads, bridges/culverts/fords, rubbish, drain input, water extraction points, stock access,

sedimentation, invasive exotic vegetation, barriers to fish passage, channelization and hydrological alterations; together with a severity rating (i.e. high, medium, low) applied to the disturbance sources that were identified at a given site.

Water quality measurements (dissolved oxygen (mg/L), pH, temperature (degrees Celsius), conductivity (mS/cm)) were made with a calibrated Horiba U-52 water quality meter.

4 Results

4.1 Macroinvertebrates

The macroinvertebrate site results based on combined data from each site sampled are provided in Table 3, for comparison against previous results (GHD 2010-2017, Ecology Australia 2018).

None of the samples collected contained sufficient macroinvertebrates to enable the sample to be picked in 30 minutes (each one had considerably less than 200 macroinvertebrates) and two sites were so depauperate that the combined data from three samples did not add up to 200 macroinvertebrates. Site W2/3 had the fewest taxa present, with only nine taxa detected across the three samples, and in one sample only four taxa were detected. This is substantially less than the State Environmental Protection Policy (SEPP) – Waters of Victoria (WoV) objective (Vic. Gov. 2003) of 24 taxa. No samples attained SEPP objectives for number of taxa, and even as combined samples by site there were no sites that achieved this objective.

None of the sites attained SEPP–WoV objectives for EPA key families, and even the three sites combined were unable to attain the objectives, with W2/3 again performing considerably worse than all other sampled sites. As combined sites, the highest number of taxa detected was 19, which occurred at two of the sites sampled.

Three sites attained SEPP–WoV objectives for SIGNAL scores when the three samples were combined, with BC1 attaining the highest score. BCT1 attained the highest diversity for both EPT and EPTO, but still failed to meet the SEPP–WoV objectives.

Table 3 Site macroinvertebrate indices results (non-attainment of SEPP objectives indicated by shading)

Indices	W2/3	SC1	BCT1	BCT2	BC1	BC2	BC3	UAR1	UAR2	SEPP objective*
# taxa	9	18	19	17	17	16	14	14	19	24
Abundance	209	120	143	206	400	276	281	433	242	N/A
EPA key families	6	13	12	13	12	12	11	9	11	26*
SIGNAL score	5.44	5.53	5.22	5.63	6.0	5.85	5.83	5.73	5.38	5.8
EPT	1	2	5	3	2	3	3	1	1	9
EPTO	1	2	7	3	4	3	3	2	2	N/A

4.2 Southern pygmy perch results

A total of 56 Southern pygmy perch were captured from Salt Creek (SC1), and none were captured from Breakfast Creek tributary (BCT1) (Figure 2 and Figure 3, Plate 1 and 2). These represent the fifth highest and equal lowest spring Catch Per Unit Effort (CPUE) since 2009, respectively. CPUE was calculated using number of traps deployed, based on the assumption that five bait traps were utilised each spring from 2009–2016, and ten traps were utilised in 2017 and 2018. It is unclear how many of the fish were

detected via electrofishing versus bait traps in 2009 and 2010, or how many bait traps were used between 2012 and 2016 as it is not specified in the methods (GHD 2010–2017). While CPUE is typically measured by units of time, this was not feasible due to the lack of data from previous years.

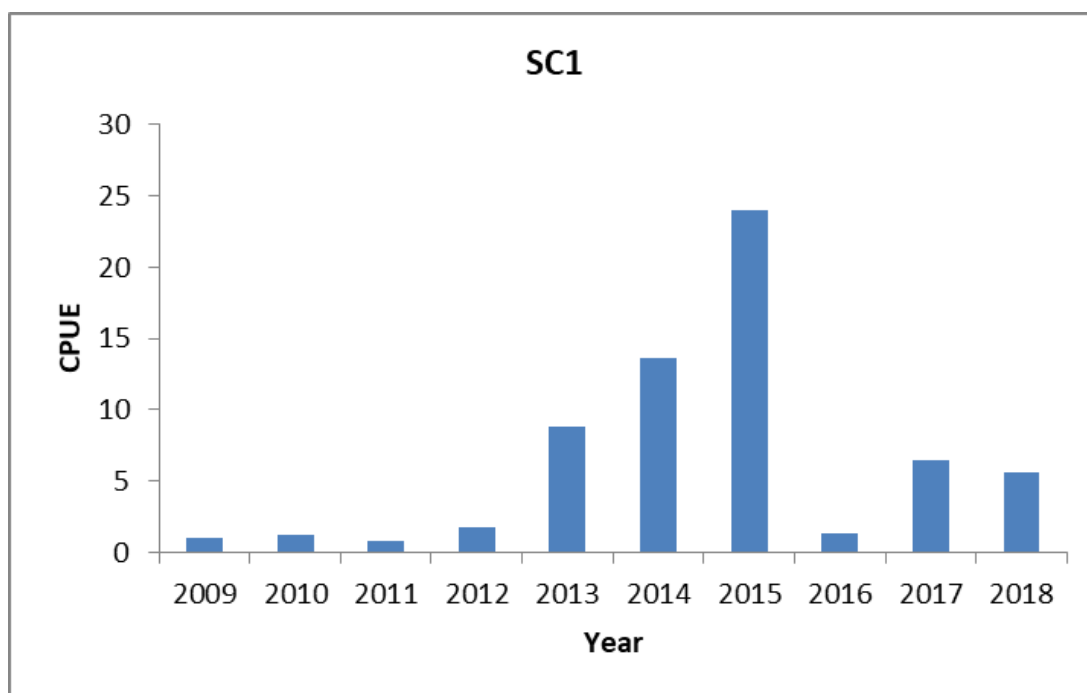
Higher total abundances had been noted from BCT1 in the three preceding years of survey, followed by a reduction to zero fish detected in 2018. Recruitment was last detected in spring 2016 (GHD 2017), which means there have been two successive spring sampling events where recruitment was not detected. However, recruitment for this and most Victorian freshwater fish species is more reliably detected by sampling fish in autumn, rather than spring. Although no fish were detected during this round of monitoring, it should be noted that none were detected in spring 2012, and the population was redetected the following autumn.

The abundance of Southern pygmy perch in SC1 appears to have been highly variable over the 11 years of monitoring, but numbers appear to have stabilised after an apparent reduction in 2016. Recruitment appears to have occurred annually at SC1.

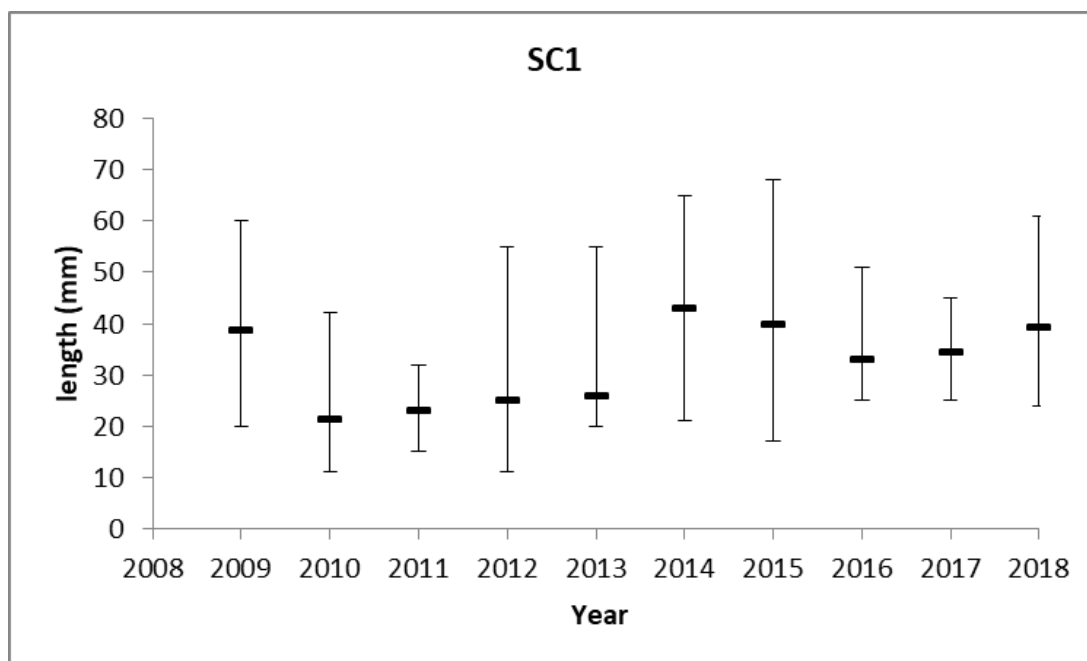
A single Short-finned eel *Anguilla australis* (approximately 500 mm) was observed while setting bait traps at BCT1.



Plate 1 Male, female and juvenile Southern pygmy perch from SC1

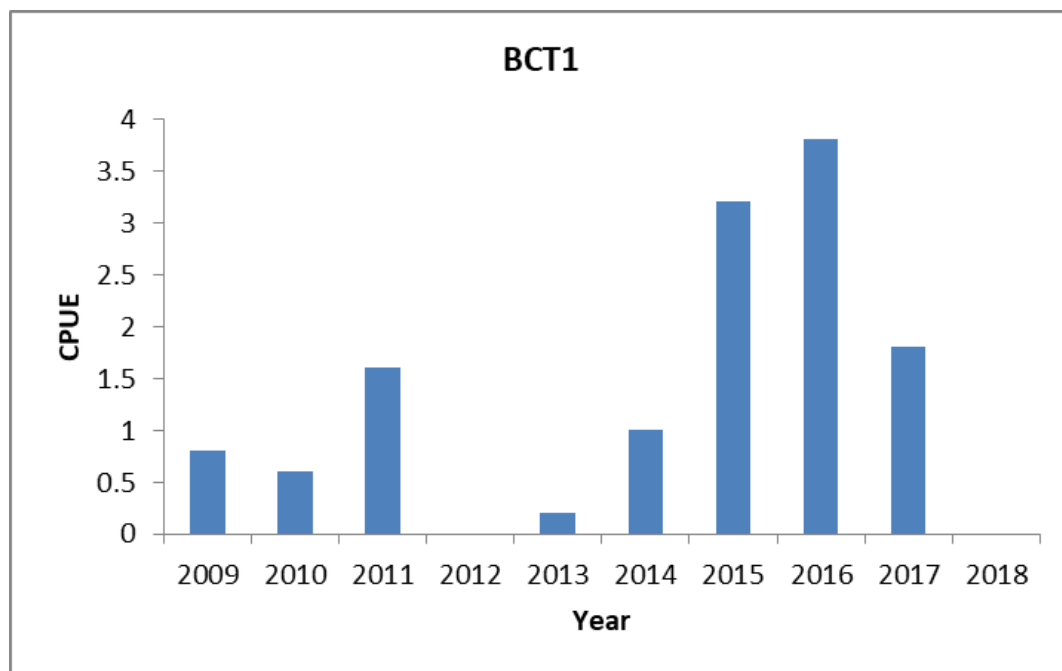


a) fish catch per unit effort at SC1.

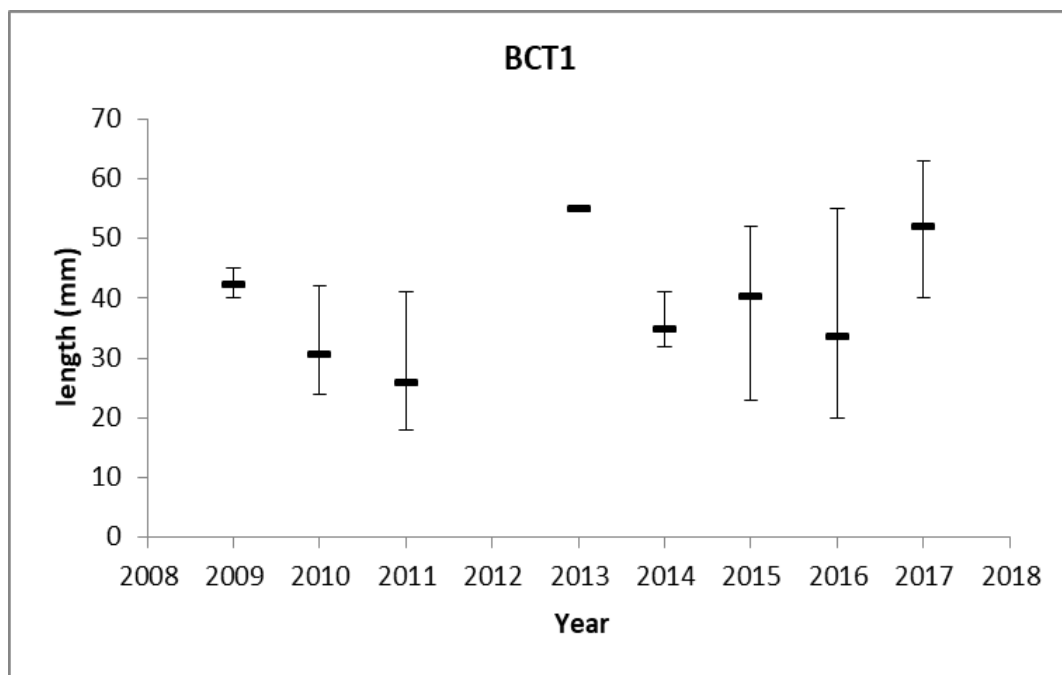


b) mean (black bars), together with minimum and maximum lengths (TL) of Southern pygmy perch. n= CPUE x5 from Figure 27a), with the exception of 2017 and 2018 where n=CPUEx10

Figure 2 Southern pygmy perch spring CPUE a), and length (TL) b) summary 2009–2018 at SC1



a) fish capture per unit effort at BCT1



b) mean (black bars), together with minimum and maximum lengths (TL) of Southern pygmy perch.
 $n = \text{CPUE} \times 5$ from Figure 27a), with the exception of 2017 and 2018 where $n = \text{CPUE} \times 10$

Figure 3 Southern pygmy perch spring CPUE a), and length (TL) b) summary 2009–2018 at BCT1

4.3 Water quality

Water quality results, whilst not consistently indicating attainment of SEPP objectives for conductivity, dissolved oxygen and pH, were fairly consistent with results from previous years (GHD 2010–17, Ecology Australia 2018) (Table 4). It should be noted that to accurately assess against SEPP-WoV indices, a minimum of 11 data points are required from a single year, hence single snap-shot measurements provide a poor indication of compliance.

Table 4 In situ water quality results (shading represents potential non-compliance with SEPP objectives, pink for measurements that indicate failure against both SEPP-WoV and SEPP-W, orange for measurements that indicate failure against one)

	Temperature (°C)	Conductivity (s/cm)	Dissolved oxygen		pH
			mg/L	%Sat	
SEPP-WoV objective		<500 (75 th percentile)		>90 (25 th percentile)	6.4-7.7 (25 th -75 th percentile)
SEPP-W objective		<200 (75 th percentile)		>85 (25 th percentile)	6.5-7.5 (25 th -75 th percentile)
UAR1					
UAR2	18.2	844	8.1	86	6.62
BC1	16.82	1930	6.72	71.9	7.12
BC2	12.67	339	5.12	51	5.16
BC3	14.10	368	2.8	28.2	3.15
BCT1	13.22	291	5.84	57.6	5.45
BCT2	14.0	292	6.9	69	4.94
SC1	13.48	321	6.33	62.8	5.23
W1*					
W2&3	13.54	4960	3.57	35.9	2.61

*W1 had insufficient surface water to take water quality readings

4.4 Otway bush yabby

Otway bush yabby *Geocharax gracilis* is a small freshwater crayfish listed as Endangered on the Victorian Advisory List of threatened invertebrates (DSE 2009). The species Otway bush yabby was detected at six of the eleven surveys locations, including repeat detections at the two study sites where they were detected in 2017 (Ecology Australia 2018), and four new sites. Otway bush yabby were detected during the fish survey (bait traps), during the macroinvertebrate survey (dip nets), and during additional, targeted dip netting (Table 5). A total of 126 individuals were detected. There are no local records of this species on the Victorian Biodiversity Atlas (DELWP 2017), however there is a published record from Salt Creek c.2007 (Schultz et al. 2007). Upon discovery in 2017 it was requested by Mark Dodgshun of Barwon Water that this species be monitored concurrently with the effort that was being employed for fish and macroinvertebrates (Ecology Australia 2018).

Table 5 Records of Otway bush yabby (spring 2018)

Site	Macroinvertebrate sampling	Bait trapping	Additional dip netting
UAR1	14*		
UAR2	5*		
BC1	0		
BC2	6*		
BC3	0		
BCT1	30	5	28
BCT2	27*		
SC1	4	1	6
W1			
W2&3	0		

*new record



Plate 2 Otway bush yabby, mature and juvenile specimens – Breakfast Creek tributary (BCT1)



Plate 3 Otway bush yabby – BC2

4.5 Aquatic monitoring results by site

Wetland 1

At the time of survey, Wetland 1 had very limited surface water and was deemed unsuitable for survey. Water depth was a maximum of 5 cm, which precluded taking water quality readings. The substrate was predominantly clay/silt, with *Juncus* spp., Paperbark and Tea-tree throughout the site (Plate 4).



Plate 4 Wetland 1 showing insufficient surface water for sampling

Wetland 2 and 3

At the time of survey, Wetlands 2 and 3 were very shallow, contracted, and dominated by dense Paperbark and Tea-tree. These two wetlands are connected and hence do not constitute independent sites. Additionally, at the time of survey there was insufficient surface water present in either wetland to collect three samples, so after discussions with Mark Dodgshun, Wetlands 2 and 3 were converted to a single site.

The substrate was predominantly clay/silt, with a gravel track running adjacent to the site and presenting a potential point source of pollutants and sediment. Filamentous algae, macrophytes and coarse particulate organic matter were present in moderate abundance. The majority of the site exhibited no obvious flow, with the exception of a small channel crossing under the track. Despite combining the two wetlands, this site had very limited standing water; had there been any less the site would have been ruled out. At the time of sampling, the water quality readings indicated that it was far from meeting SEPP objectives for pH, conductivity and dissolved oxygen.

The macroinvertebrate results for the wetland site were poor for all indices (Table 6). Site W2/3 has regularly been dry at the time of survey, or an alternative wetland site has been surveyed.

Macroinvertebrate sampling results from Wetland 2/3 were broadly similar with the most recent survey in 2017 (Ecology Australia 2018); with minor improvements were observed across all indices despite massive increases in electrical conductivity.

Table 6 Macroinvertebrate sample results at W2/3, displayed individually and combined for the site, showing SEPP objectives (shading indicates potential non-attainment of SEPP objectives)

	W2/3-1	W2/3-2	W2/3-3	SEPP-W objective	W2/3	SEPP-WoV objective
# taxa	4	6	6	17	9	24
Abundance	111	41	57	-	209	-
Key families	2	5	3	-	6	26
SIGNAL	5.5	5.0	5.7	-	5.44	5.8
SIGNAL2	2.8	3.2	2.7	4.2		
EPT	0	1	0	6	1	9
EPTO	0	1	0	-	1	-

Salt Creek (SC1)



Plate 5 Salt Creek at SC1

Salt Creek at SC1 had one of the largest areas of surface water available for sampling, and appeared permanent. The substrate was silt/clay, and the flow velocity was dominated by lentic (still) habitats with small sections of glide. The main instream cover available for fish and macroinvertebrates, in decreasing order of prevalence, consisted of coarse particulate organic matter (e.g. leaves and other organic debris), loose silt lying on the surface, overhanging terrestrial vegetation, aquatic vegetation, branches, overhanging bank and logs. There was some evidence of deer damage (pugging) around the site. The dominant aquatic vegetation types were *Juncus* spp., *Carex* spp. and *Isolepis* spp.

The macroinvertebrate results for Salt Creek failed to attain SEPP objectives for all indices with the exception of the SIGNAL and SIGNAL2 score for one of the three samples (Table 7). No EPT or EPTO taxa were detected in two of the three samples. SC1 has been surveyed annually, and was last surveyed in 2017 (Ecology Australia 2018). The pH and dissolved oxygen levels both showed improvements, while the macroinvertebrate results showed declines against all measurements. However, the macroinvertebrate results are largely better or similar to the results from 2014–2016 (GHD 2015–2017), with the exception of a lower SIGNAL score.

Table 7 Macroinvertebrate sample results at SC1, displayed individually and combined for the site, showing SEPP objectives

	SC1-1	SC1-2	SC1-3	SEPP-W objective	SC1	SEPP-WoV objective
# taxa	10	12	13	17	18	24
Abundance	47	20	50	-	117	-
Key families	7	9	8	-	13	26
SIGNAL	5.5	5.8	4.9	-	5.5	5.8
SIGNAL2	3.5	4.3	3.3	4.2		
EPT	0	2*	0	6	2*	9
EPTO	0	2*	0	-	2*	-

*additional taxa present at genus level

Southern pygmy perch total abundance and CPUE were slightly lower than the previous year, and remain substantially lower than 2015. The length-frequency histogram shows there are multiple age classes present at SC1, and that successful recruitment has occurred in the past 12 months. Southern pygmy perch reach maturity at approximately 30–33 mm (Knight 2008), and 12–13 of the 56 fish detected were below this threshold (Figure 4).

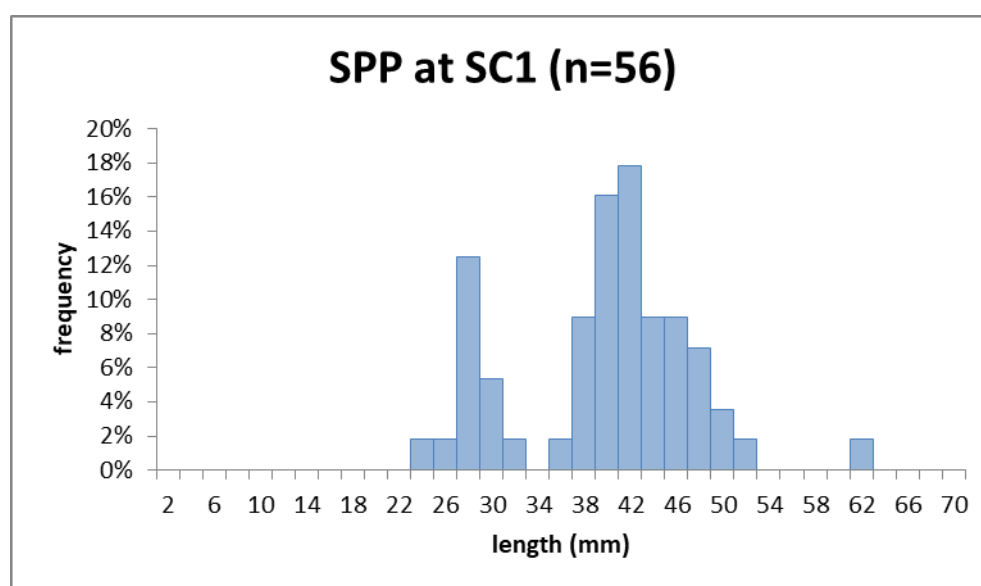


Figure 4 Length-frequency histogram of Southern pygmy perch at SC1.

Breakfast Creek tributary 1 (BCT1) at SV3

Plate 6 Breakfast Creek tributary (BCT1) at SV3, showing stream gauge

Breakfast Creek tributary at SV3 (relocated BCT1) consisted of a narrow, shallow stream, with a maximum width of 1 m. The substrate was silt/clay, and the flow velocity was dominated by lentic (still) habitats with less than 15% glide within the surveyed reach. The main instream cover available for fish and macroinvertebrates, in decreasing order of prevalence, consisted of coarse particulate organic matter (e.g. leaves and other organic debris), loose silt lying on the surface, overhanging terrestrial vegetation, woody debris, aquatic vegetation, overhanging bank and moss. The dominant aquatic vegetation type was *Blechnum* sp. The water level was slightly lower than in 2017, based on the site photographs, and stream gauge SV3 (235274A) data provided by Tom Scarborough of Barwon Water. During the sampling period in 2017, the water level ranged from 0.125–0.144 m and discharge ranged from 0.02–0.08 ML/day, whereas in 2018 the water level was 0.1–0.112 m and discharge was <0.003 ML/day.

Similarly to SC1, the macroinvertebrate results for the Breakfast Creek tributary site 1 failed to attain SEPP objectives for every index with the exception of SIGNAL score, of which two of the individual samples met the required score, and SIGNAL2 where all samples met the required score (Table 8). Whilst failing to meet the objectives, BCT1 results were superior to other sites for number of taxa, number of EPT taxa, and number of EPTO taxa. BCT1 showed slight declines against measured indicators for macroinvertebrates compared with 2017 results (Ecology Australia 2018), despite no major changes in water quality levels. Site BCT1 has been sampled annually. The results from the past few years are fairly consistent, with some indices improving and others declining marginally. Compared with 2014–2016 (GHD 2015–16), the number of taxa, EPT and EPTO indices have improved, while key families are similar and the SIGNAL score has dropped.

Table 8 Macroinvertebrate individual sample and combined sample results at BCT1 and the SEPP objectives (shading indicates non-compliance with objectives)

	BCT1-1	BCT1-2	BCT1-3	SEPP-W objective	BCT1	SEPP-WoV objective
# taxa	10	15	8	17	19	24
Abundance	45	63	35	-	143	-
Key families	7	11	7	-	12	26
SIGNAL	6.2	5.6	6.4	-	5.6	5.8
SIGNAL2	5.6	4.3	5.3	4.2		
EPT	2	4	3	6	5	9
EPTO	4	5	3	-	7	-

No Southern pygmy perch were detected during this round of monitoring. The length-frequency histogram from 2017 suggests that recruitment failure may have occurred, however detection of recruitment has been inconsistent at this site throughout the 11 years of monitoring. Southern pygmy perch reach maturity at approximately 30–33 mm TL (Knight 2008), and none of the fish detected in 2017 were below this threshold. However, recruitment is more reliably detected by autumn rather than spring sampling. Additionally, growth rates of fish can be highly variable between sites depending on factors such as temperature and resource availability, so length alone can be a very coarse measurement of recruitment. Two additional bait traps were deployed downstream of the stream gauge, however these also failed to detect any fish. It should be noted that a single Short-finned eel (approximately 500 mm TL) was observed within the site whilst setting the bait traps. This species is omnivorous and is likely to prey upon both Southern pygmy perch and Otways bush yabby.

Breakfast Creek tributary 2 (BCT2)**Plate 7 Breakfast Creek tributary 2 (BCT2)**

Breakfast Creek tributary at BCT2 was sampled as two small pools. The pH and dissolved oxygen levels were both low. The substrate was silt/clay, and the site was solely made up of lentic (still) habitat. The main instream cover available for macroinvertebrates, in decreasing order of prevalence, consisted of coarse particulate organic matter (e.g. leaves and other organic debris), trailing bank vegetation, loose silt lying on the surface, aquatic vegetation and overhanging bank. The dominant aquatic vegetation types were *Carex* spp. and ferns trailing in the water.

The macroinvertebrate results for Breakfast Creek tributary 2 were similar to those for BCT1 and SC1; failing to meet any SEPP objectives with the exceptions of a single sample which achieved the objective for SIGNAL score, and SIGNAL2 where all samples met the objective (Table 9). No prior surveys have been conducted at BCT2 due to insufficient surface water. The site performed similarly to other sites surveyed this year, despite being consistently too dry to sample in the past.

Table 9 Macroinvertebrate individual sample and combined sample results at BCT2 and the SEPP objectives (shading indicates non-compliance with objectives)

	BCT2-1	BCT2-2	BCT2-3	SEPP-W objective	BCT2	SEPP objective
# taxa	13	13	12	17	17	24
Abundance	69	67	63	-	206	-
Key families	11	11	10	-	13	26
SIGNAL	5.7	5.8	5.6	-	5.6	5.8
SIGNAL2	4.6	4.2	4.2	4.2		
EPT	3	3	3	6	3	9
EPTO	3	3	3	-	3	-

Breakfast Creek 1 (BC1)



Plate 8 Breakfast Creek at BC1

Breakfast Creek at BC1 had contracted to isolated pools at the time of sampling, and consisted of three pools each approximately 8 m long. The flow velocity was dominated by lentic (still) habitats with small sections of glide. The substrate covered all size classes from clay/silt through to bedrock, with bedrock and boulder being the dominant classes present (each approximately 25%). The main instream cover categories present for macroinvertebrates, in decreasing order of prevalence were loose silt lying on substrate, coarse particulate organic matter, undercut banks, trailing bank vegetation and moss. The only aquatic vegetation noted was *Carex* spp. Small patches of exotic groundcover were noted in a largely intact riparian zone. The conductivity at this site was elevated, at 1.93 mS/cm, and much higher compared with the other two sites sampled on Breakfast Creek.

The macroinvertebrate results for Breakfast Creek at BC1 did not attain SEPP objectives for number of taxa, key families or number of EPT taxa (Table 10). The SIGNAL scores largely indicated that the water quality of the site was classified as clean water, and that it attained SEPP-WoV objectives for this index. One of the three samples attained the SEPP-W objective for SIGNAL2. BC1 in 2018 recorded much higher electrical conductivity levels but showed improvements in dissolved oxygen and pH levels compared with spring 2010 (GHD 2011). The macroinvertebrate results show slight improvements.

Table 10 Macroinvertebrate individual sample and combined sample results at BC1 and the SEPP objectives (shading indicates non-compliance with objectives)

	BC1-1	BC1-2	BC1-3	SEPP-W objective	BC1	SEPP objective
# taxa	9	11	10	17	17	24
Abundance	141	138	121	-	400	-
Key families	6	7	7	-	12	26
SIGNAL	7	5.8	6.2	-	6.0	5.8
SIGNAL2	3.9	4.8	4	4.2		
EPT	2*	2	2*	6	2*	9
EPTO	2*	4	2*	-	4*	-

*additional taxa present at genus level

Breakfast Creek 2 (BC2)**Plate 9 Breakfast Creek at BC2**

Breakfast Creek at BC2 was deeply incised and shallow, and the pH and dissolved oxygen levels were low. The substrate was predominantly silt/clay with small proportions of bedrock and boulder. The flow velocity was zero throughout the sampled reach. The main instream cover available for aquatic fauna, in decreasing order of prevalence, consisted of coarse particulate organic matter (e.g. leaves and other organic debris), loose silt lying on the surface, overhanging terrestrial vegetation, overhanging bank and logs. No aquatic vegetation was noted, however ferns trailed into the water.

The macroinvertebrate results for Breakfast Creek at BC2 did not attain SEPP objectives for number of taxa, number of key families, or number of EPT taxa as individual or combined samples (Table 11). The SIGNAL scores indicated that the site suffers from mild pollution, but attained SEPP objectives for this index. All three samples attained SEPP-W objectives for SIGNAL2. BC2 water quality and macroinvertebrate results appear broadly in agreement between 2013 (GHD 2014) and 2018.

Table 11 Macroinvertebrate sample results at BC2, displayed individually and combined for the site, showing SEPP objectives

	BC2-1	BC2-2	BC2-3	SEPP-W objective	BC2	SEPP objective
# taxa	14	13	12	17	16	24
Abundance	69	91	115	-	276	-
Key families	10	10	11	-	12	26
SIGNAL	5.9	6.3	6.4	-	5.85	5.8
SIGNAL2	4.2	4.3	4.4	4.2		
EPT	3*	3	3	6	3*	9
EPTO	3*	3	3	-	3*	-

*additional taxa present at genus level

Breakfast Creek 3 (BC3)



Plate 10 Breakfast Creek at BC3

Breakfast Creek at BC3 had the largest area of surface water available for sampling but dissolved oxygen and pH levels were low. The substrate was dominated by sand, with some pebbles, gravel and clay/silt, and consisted entirely of lentic (still) habitats. The main instream cover available for macroinvertebrates, in decreasing order of prevalence, consisted of coarse particulate organic matter (e.g. leaves and other organic debris), loose silt lying on the surface, overhanging terrestrial vegetation, aquatic vegetation, overhanging bank, roots and logs. The dominant aquatic vegetation type was *Carex* spp.

The macroinvertebrate results for Breakfast Creek at BC3 did not attain SEPP objectives for number of taxa, number of key families, or number of EPT taxa (Table 12). Similarly to the other two Breakfast Creek sites, BC3 attained SEPP-WoV objectives for SIGNAL. Only one of the three samples attained SEPP-W objectives for SIGNAL2. Water quality at BC3 has declined since the last readings taken in 2013 (GHD 2014), particularly pH but also dissolved oxygen and turbidity, which may account for the reductions in EPT and EPTO taxa recorded in the current round of monitoring.

Table 12 Macroinvertebrate sample results at BC3, displayed individually and combined for the site, showing SEPP objectives

	BC3-1	BC3-2	BC3-3	SEPP-W objective	BC3	SEPP objective
# taxa	11	10	9	17	14	24
Abundance	93	92	95	-	281	-
Key families	8	8	8	-	11	26
SIGNAL	7	6.1	6.1	-	5.83	5.8
SIGNAL2	4.5	4.1	4	4.2		
EPT	3	2	2	6	3	9
EPTO	3	2	2	-	3	-

Upper Anglesea River 1 (UAR1)



Plate 11 Upper Anglesea River at UAR1

The sampled reach of Anglesea River at UAR1 was made up of three isolated pools. The substrate was predominantly silt/clay, with some gravel and sand present. There was no flow within the sampled reach. The main instream cover available for aquatic fauna, in decreasing order of prevalence, consisted of aquatic vegetation, coarse particulate organic matter (e.g. leaves and other organic debris), loose silt lying on the surface, trailing bank vegetation, overhanging bank and logs. The dominant aquatic vegetation types were *Triglochin/Cycnogeton* spp., unknown grass-like submerged vegetation, *Juncus* spp., *Carex* spp. and *Myriophyllum* spp. Several trail bike tracks in the vicinity, including upstream of the sampled reach, were resulting in erosion and likely increased sedimentation.

The macroinvertebrate results for Upper Anglesea River at UAR1 failed to attain SEPP objectives for number of taxa, key families, SIGNAL2 and EPT taxa (Table 13). The SIGNAL scores indicated that the site suffers from mild pollution, and two of the three samples attained SEPP-WoV objectives for this index. The macroinvertebrate results from UAR1 are broadly similar with those achieved in spring 2013 (GHD 2014).

Table 13 Macroinvertebrate sample results at UAR1, displayed individually and combined for the site, showing SEPP objectives

	UAR1-1	UAR1-2	UAR1-3	SEPP-W objective	UAR1	SEPP objective
# taxa	14	11	10	17	14	24
Abundance	169	130	133	-	433	-
Key families	9	6	6	-	9	26
SIGNAL	5.7	6.0	5.9	-	5.73	5.8
SIGNAL2	3.3	3	3	4.2		
EPT	1	1	1	6	1	9
EPTO	2	2	2	-	2	-

Upper Anglesea River 2 (UAR2)



Plate 12 Upper Anglesea River 2 (UAR2)

Upper Anglesea River at UAR2 consisted of a 30 m pool, with a maximum width of 7 m. No flow was present within the sampled reach and the conductivity was quite high (0.844 mS/cm). The substrate was predominantly silt/clay, with small amounts of sand. The main instream habitats providing habitat for macroinvertebrates were loose silt lying on the surface, coarse particulate organic matter, macrophytes, snags and moss. The dominant aquatic vegetation types were submerged, feather-like vegetation, *Cyanogeton/Triglochin* spp. and *Carex* spp.

Similarly to UAR1, the macroinvertebrate results for Upper Anglesea River at UAR2 also failed to attain SEPP objectives for number of taxa, key families, SIGNAL2 and EPT taxa (Table 14). The SIGNAL scores indicated that the site suffers from mild pollution, but two of the three samples attained the SEPP objective. UAR2 water quality readings showed some improvements compared with the previous sampling in 2013 (GHD 2014), with dissolved oxygen and pH levels both improving to indicate compliance with SEPP objectives. Despite these improvements, there were marked reductions in overall abundance and number of EPTO taxa.

Table 14 Macroinvertebrate sample results at UAR2, displayed individually and combined for the site, showing SEPP objectives

	UAR2-1	UAR2-2	UAR2-3	SEPP-W objective	UAR2	SEPP objective
# taxa	13	13	17	17	19	24
Abundance	96	79	77	-	252	-
Key families	8	8	10	-	11	26
SIGNAL	5.8	6.2	5.6	-	5.38	5.8
SIGNAL2	3.2	3.5	3.5	4.2		
EPT	0	1	1	6	1	9
EPTO	1	2	2	-	2	-

5 Discussion

Macroinvertebrate surveys are regularly employed to provide an overview of the condition or 'health' of aquatic systems due to the relatively rapid nature of the assessment. The macroinvertebrate survey results were relatively consistent with previous years, with sites demonstrating slight improvements for some indices, and minor reductions in others.

The last time the full complement of sites were due to be sampled in spring was in 2015. At this time, BC1, BC2, BC3, BCT2, UAR1 and UAR2 were dry (GHD 2016). For the current round of monitoring, site W1 was dry, and W2 and W3 were combined due to lack of site fidelity and insufficient water for either to be sampled individually.

The use of multiple indices to analyse the status of the macroinvertebrate communities enhances the capacity to assess the state of the communities, and hence the state of the aquatic systems, by mitigating for limitations in individual indices (Tiller and Metzeling 2002). However, it should be noted that comparisons between these results and SEPP-WoV objectives (Vic. Gov. 2003) are provided for consistency with previous reports and should be interpreted with caution. The SEPP objectives are based on the standard RBA methods. Sampling undertaken for this project consisted of triplicate edge, single season samples from predominantly lentic habitats; while standard RBA sampling entails edge and riffle samples collected in both spring and autumn from predominantly lotic habitats and never from wetlands. As a result, it is probably more appropriate to track the progress of each site against baseline data, rather than make only semi-valid comparisons against the objectives.

Simplifying macroinvertebrate tolerance to a single score per family (SIGNAL) allows for more rapid assessment, but comes at a cost. Macroinvertebrate tolerance varies both within families, and in relation to different pollutants, physicochemical parameters and habitat variability (EPA 2004).

The low abundance and diversity of macroinvertebrates detected, and poor performance against SEPP objectives could be attributed to a few different factors. Due to the limited surface water present at all sites, all, or nearly all available surface water was sampled at every suitable site. This is likely to impact upon the results, as this reduces the degree of selectiveness that can be employed in sampling all microhabitats present; and it is possible that some sites may not have been wetted for a sufficient period for colonisation/re-colonisation by the full complement of potential species. Additionally, the reduction in connectivity between sites influences colonisation, and is further influenced by the motility of each taxa. The impacts of acid sulphate soils and/or acid events can result in low pH levels, most notably in Wetland 2/3. The lack of surface water as a result of evapotranspiration is likely to further reduce the suitability for macroinvertebrates and other aquatic life, as physicochemical parameters (such as salinity and temperature) become more extreme; as demonstrated by the high electrical conductivity noted at sites BC1 and particularly W2/3.

Although the water quality readings cannot reliably be compared against SEPP-WoV objectives as they do not meet the requirements of 11 readings per site over the course of 12 months, they can indicate likelihood of compliance. Of the eight sites where in situ water quality assessments were taken, only one was indicative of meeting the SEPP-WoV objectives for dissolved oxygen levels, and only two for pH and five for conductivity. Of the three sites that appeared likely to fail to meet the SEPP objectives for conductivity, one measured nearly ten times higher than the 75th percentile to meet the objective. W2/3 again exhibited a considerably lower pH level than other sites that were sampled, which is likely to have an impact upon the biota present as a pH of 2.61 is likely to be inhospitable for the vast majority of

taxa. While low, low pH is characteristic of the wetland sites (Ecology Australia, unpublished data). In addition, having rarely contained sufficient water for survey (prior to 2017 it was last surveyed in 2011) the short hydroperiod of this wetland is likely to greatly influence the macroinvertebrate community composition and abundance.

The Southern pygmy perch population in the Anglesea catchment was identified as genetically distinct from surrounding catchments, and at the time of genetic assessment, the historically abundant populations from the Anglesea River and surrounding wetlands were not detected (Cesar 2012). Based on work conducted on this species by Hammer (2008) and the overall life history of the species, this is unsurprising. Hammer (2008) identified the species as demonstrating limited localised movement, inhabiting multiple isolated drainages, and exhibiting broad genetic sub-structure throughout its range. Further to the limited dispersal capability of the species are the compounding impacts of short life-span and numerous threatening processes (including introduced species, habitat degradation and destruction, and climate change), which results in higher likelihood of localised extirpation (Todd et al. 2017, Wedderburn, Hammer and Bice 2012).

If further surveys of Southern pygmy perch in the broader catchment area were to be undertaken and yield similar results to that found previously (Cesar 2012), then the populations present in Salt Creek and Breakfast Creek tributary may be important source populations for recolonisation lower in the catchment. During the 2017 spring surveys for Southern pygmy perch, the species was detected at both survey sites, however in spring 2018 no Southern pygmy perch were detected in BCT1. Southern pygmy perch have been detected at both sites in every spring survey since 2010, with the exception of 2012 and 2018 at BCT1. The population at BCT1 has previously persisted despite three successive spring sampling events whereby no recruits were detected (2012–14) (GHD 2013–2015). Appearance and reappearance at BCT1 may indicate that the site does not encompass the local Breakfast Creek source population. In Salt Creek, the population appears to have had successful recruitment in the past 12 months at SC1, and the abundance appears to have stabilised after a drop in 2016. While the review of the MAP (GHD 2013b) suggested the BCT1 population was more stable, more recent surveys have detected more individuals and more consistent evidence of recruitment at SC1.

Based on the length-frequency histogram of Southern pygmy perch at SC1, young of year Southern pygmy perch and/or 1+ Southern pygmy perch for the current year of monitoring are likely to be 32 mm. As a species that breeds predominantly in spring, and based on the spring timing of sampling, these fish are likely to be closer to or just over 1+. This size range is largely in agreement with Knight (2008), whereby males reach maturity at 30 mm and females at 33 mm.

The detection of a Short-finned eel at BCT1 suggests that further work may be warranted to determine the fish fauna within the catchment, as the exclusive use of bait traps is a poor sampling method for most fish species and no other fish species have been detected over the duration of the monitoring program.

The most notable result from the aquatic ecological monitoring in 2017 and 2018 was the detection of the endangered Otway bush yabby. This species has previously been recorded in this region in 2007 (Schultz 2007), however 2017 was the first time it was recorded as part of this monitoring program. Based on the abundance and size ranges encountered, it is likely that this species has maintained a population in the Breakfast Creek and Salt Creek catchments throughout the monitoring period. The species was detected at an additional four sites in 2018, including from the upper Anglesea River.

Recommendations

- Due to the limited presence of surface water, it may be beneficial to reduce the number of macroinvertebrate samples per site from three down to two, to avoid oversampling which likely results in poorer results per sample. As the new SEPP-W indices for macroinvertebrates are based on single samples, the importance of collecting quality samples is enhanced.
- Given the recent failure to detect Southern pygmy perch at BCT1, it would be beneficial to reassess the catchment for additional populations. This has not been done since 2012, and would ideally focus on historic records from Anglesea River and associated wetlands and Breakfast Creek in addition to known refuge pools throughout Salt Creek and Anglesea River (as identified in GHD 2010), and an investigation into refuge pools in the Breakfast Creek catchment. As a genetically distinct population in an isolated catchment, it is of concern that the species may have retracted to a single remnant population. This results in a high level of vulnerability for this genetic lineage.
- Consideration should be given to the inclusion of Otway bush yabby in the monitoring program in future years, including investigations into the extent of the population throughout the study area.

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Appendix 1 Results of macroinvertebrate sampling

Taxa	BC1-E1	BC1-E2	BC1-E3	BC2-E1	BC2-E2	BC2-E3	BC3-E1	BC3-E2	BC3-E3	BCT1-E1	BCT1-E2	BCT1-E3	BCT2-E1	BCT2-E2	BCT2-E3	SC1-E1	SC1-E2	SC1-E3	UAR1-E1	UAR1-E2	UAR1-E3	UAR2-E1	UAR2-E2	UAR2-E3	W2/3-E1	W2/3-E2	W2/3-E3	Grand Total
Acarina	1	1			1	1	2			3	2	1		1		3	1	2	1			1	1	2				24
Ceinidae																			47	36	53	1	2	1				140
Ceratopogonidae											1																1	
Chironominae	1	32	1	18	26	18	2	6	20	3	13	4	4	1	1	3	1	7	1	1	1			1			165	
Dixidae			1																								1	
Dytiscidae A	5	15	4	6	14	17	9	12	8				2			3	2	6	9	14	6	15	11	11	3	1	5	178
Ecnomidae - Ecnomina											3																3	
Geocharax gracilis				2	2	2				12	11	7	8	8	11	4			5	4	5	5	5	5				96
Gripopterygidae - Dinotoperla										5	3	3	4	4	3												22	
Dytiscidae L	3		1	3	5	6	15	12	12									1	2			3	5	6			74	
Hydrophilidae A	2		1										3		1	1	1					4	3	1		1	18	
Leptoceridae - Leptorussa	84	32	48	1		3	4	1	1								1		5	6	5		1	2		1	195	
Leptoceridae - Triplectides				1	2					11	17	17	9	2	12		1										72	
Leptoceridae - Triplectides/Triplectidina	32		9																								41	
Leptophlebiidae - Nousia		38	37	4	13	14	14	26	21		1		8	5	18		1										200	
Leptophlebiidae - Ulmerophlebia	7																										7	
Notonectidae																									1		1	
Oligochaeta		1		9	1	5		4	3	1	1		4	1	1			5				2		1			39	
Orthoclaudiinae				2	1	7	8		2	2	1	1	5	5	3	3	3	1	1								45	
Leptoceridae	1																										1	
Polycentropodidae - Neureclipsis				1	3	1	1					1															7	
Scirtidae L		1		1	3	3	1	2	3				2	2	1			1	15	7	7	28	21	8	30	5	16	157
Simuliidae																	1										1	
Leptophlebiidae	1																										1	
Tanypodinae			1	5		2		2	1		4		8	9				2				2	2	1			39	
Tipulidae								1																			1	
Veliidae														2	1	20	4	14	1				4		1		47	
Argiolestidae - Austroargiolestes		1								1	2																4	
Culicidae	3	13	17	14	18	36	32	25	24		2		11	26	8			1	44	40	32	13	8	15	60	27	23	492
Curculionidae A																									18		11	29
Gordiidae														1													1	
Hydraenidae A	1		1				1									1		1	1	1		1				1	9	
Hydrochidae A				1	1		4	1								6	3	1	23	7	11	9	11	8			86	
Janiridae					1						1				3									2			7	
Koonungidae																		3	3	11	4						21	
Lestidae - Austrolestes																			11	3	9	3	2	1			29	
Nannochoristidae										2																	2	
Paramelitidae												1	1			3	1	5					1				12	
Phreatoicidae																						9	6	7			22	
Podonominae																								1			1	
Pyralidae				1																							1	
Sphaeriidae		3																									3	
Talitridae											1																1	
Telephlebiidae - Austroaeschna		1								3																	4	
Grand Total	141	138	121	69	91	115	93	92	95	43	63	35	69	67	63	47	20	50	169	130	133	96	79	77	111	36	57	2300



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Anglesea Borefield Ecological Monitoring and Assessment Program 2017



Prepared for: Barwon Water

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- Emma Danby Parks Victoria

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Summary

Background

The revised Monitoring and Assessment Program (MAP) (Victorian Government 2014) is a requirement for the Anglesea Borefield Project (ABP) initiated under the Bulk Entitlement (BE) order 2009. The ABP was put in place to meet water demands of Geelong and surrounding areas when they exceed the capacity of regular water supplies.

This report provides the 2017 monitoring results of the terrestrial (vegetation and frogs) and aquatic components of the MAP which was designed to assess the impacts of water draw down on the environment and the programs long term sustainability.

Currently the Anglesea swamp and estuary are required to be monitored biennially under non water draw down periods and at present there are no plans to undertake water drawdown. The estuary was last monitored in 2015 and the swamp was monitored in 2016. Both the estuary and the swamp were monitored again in 2017 to align monitoring timing.

Terrestrial data were collected from permanent monitoring sites, six in the swamp plus an extra two frog monitoring sites, and four sites in the estuary. The data includes floristics and Ecological Vegetation Classes (EVCs), used to determine the hydroecology of the plants and EVCs expressed in functional groups. Other data collected included structural attributes and wetland boundaries.

Frog survey data collected included species richness, abundance and habitat attributes.

The aquatic monitoring included macroinvertebrate surveys at three sites (W3, SC1 and BCT1), and targeted Southern Pygmy Perch *Nannoperca australis* surveys at two sites (SC1 and BCT1). Opportunistic backpack electrofishing was also undertaken at one site (Breakfast Creek upstream of Breakfast Creek Road).

Results

Vegetation composition, functional groups and cover of bare ground continue to be largely unchanged in the swamp and estuary. Standing water was once again recorded at all sites in the Anglesea swamp and algal mats were present at some sites for the second successive year.

Lower frog numbers were recorded in the swamp and estuary in 2017 compared with 2016 and 2015 respectively. Three frog species (Common Froglet, Southern Brown Tree Frog and Southern Bullfrog) were recorded at one site (AS2) in the Anglesea swamp during the 2017 surveys, with no frogs recorded at other monitoring sites. One Southern Bullfrog was heard calling from one site (LAR4) in the Anglesea Estuary. Overall, frog numbers recorded during the current survey were lower, and records were obtained at fewer sites, compared with the previous surveys at both the Anglesea Swamp (in 2016) and the Anglesea Estuary (in 2015).

Rainfall is a key determinate of water levels in the swamp and sustained below average rainfall (2014-2017) is very likely associated with lower frog numbers. Populations may require a number of wet years to build up numbers. The Anglesea estuary is prone to naturally occurring acid events, and while the vegetation appears to be fairly resilient to low pH, frogs may be susceptible.

Under conditions of a drying climate, frog numbers could decline permanently as drier conditions in the swamp and associated acid events increase the vulnerability of frog populations.

The results from the macroinvertebrate surveys were consistent with previous years, showing fluctuation across various indices. The wetland site (W3) was depauperate compared with the other two sites assessed, which is likely influenced by a reduced hydroperiod and low pH.

Southern Pygmy Perch *Nannoperca australis* populations continue to persist at the Breakfast Creek tributary and Salt Creek sites. The detection of 65 fish at SC1 and 18 at BCT1 represent the fourth and third highest spring catch rates. SC1 appears to have experienced a population boom followed by bust and recovery over the same period. Recruitment success appears more regular at SC1 than BCT1.

Otways Cray *Geocharax gracilis* was detected at BCT1 and SC1 sites, and during a spot-check on Breakfast Creek. Otways Cray is listed as Endangered on the Victorian Advisory List of threatened invertebrates. This is the first time the species has been identified during the MAP, and was present in reasonable abundance. It was detected during macroinvertebrate surveys (dip netting), Southern Pygmy Perch surveys (bait trapping) and opportunistic electrofishing. This species warrants further consideration, and targeted surveys should be included in future monitoring programs.

1 Introduction

Ecology Australia was commissioned by Barwon Water to conduct the spring 2017 ecological Monitoring and Assessment Program (MAP) for the Anglesea Borefield Project (ABP). This included both the terrestrial (vegetation and frogs) and aquatic ecological (fish and macroinvertebrates) components of the revised MAP (Victorian Government 2014).

The ABP was established to access and supply ground water to Geelong and surrounding areas in periods of drought when demands placed on regular water supply sources exceed capacity.

The MAP is a requirement of the ABP under the Bulk Entitlement (BE) (Anglesea Groundwater) Order 2009, established under the Water Act 1989. It was developed and implemented in 2009 (Victorian Government 2009) to assess the impacts of water draw down on the environment and the long term sustainability of the program. Potential risks to ecological values include acid generation, reduced water table (aquifer levels) and altered surface water regime.

Ecology Australia has developed and conducted the terrestrial monitoring components to date, the details of which are provided in annual reports (Ecology Australia 2009–2013a). GHD has previously undertaken the aquatic ecology monitoring program (GHD 2010–2017). This year represents the first occasion where Ecology Australia has undertaken both the terrestrial and aquatic components of the MAP.

As required under the BE (Victorian Government 2009), a review of the MAP was carried out in 2013 and knowledge gaps were addressed (GHD 2013b, Ecology Australia 2013b). The outcome was a revised focus with terrestrial monitoring targeting specific areas identified as currently at risk, which include the Anglesea Swamp and the Anglesea Estuary. The survey protocol for aquatic monitoring under the revised MAP (Victorian Government 2014) requires:

- Annual spring monitoring of macroinvertebrates at three sites:
 - Breakfast Creek tributary (BCT1);
 - Salt Creek (SC1); and
 - Lower Anglesea River wetland (Wetland 3).
- Annual spring sampling of Southern Pygmy Perch *Nannoperca australis* at two sites:
 - Breakfast Creek tributary (BCT1); and
 - Salt Creek (SC1).
- Triennial spring sampling of macroinvertebrates at all 11 aquatic monitoring sites.

The terrestrial ecology component of the revised MAP included baseline monitoring of the Anglesea Swamp for three consecutive years (2014–2016) which is now complete (Ecology Australia 2014, 2015 & 2016). From 2017 onwards, the current MAP requires the swamp to be monitored biennially in the absence of ground water pumping, and annually during water draw down.

The estuary was last monitored in 2015 (Ecology Australia) and in the continued absence of ground water pumping, was monitored again in 2017.

To align with the Anglesea Estuary monitoring, at the request of Barwon Water, biennial monitoring of the Anglesea Swamp was commenced in 2017.

The aquatic monitoring component of the revised MAP is required annually at three sites, and 2017 represented the third time the monitoring had been conducted since the 2014 review. Triennial monitoring of all 11 sites was last completed in 2015, and will next be required in 2018.

2 Methods

The terrestrial ecology (vegetation and frog) monitoring methods that are provided here follow the revised MAP requirements and remain unchanged since the last round of monitoring conducted in 2015 and 2016 (Ecology Australia 2015, 2016), but are reproduced in this report for ease of reference.

The aquatic monitoring has not previously been carried out by Ecology Australia, the methods provided here are based on the revised MAP requirements and approaches used by GHD (2010-2017).

Under the revised MAP (Victorian Government 2014) terrestrial ecological (vegetation and frog) and aquatic ecological monitoring was conducted as required at all sites in spring (Figure 1).

2.1 Ethics and Permits

All surveys were undertaken under the following ethics and research permits granted to Ecology Australia:

- Wildlife and Small Institutions Animal Ethics Committee (WSIAEC) projects 11.16 and 12.16;
- Fisheries Research Permit 1142;
- *Wildlife Act 1975*, *Flora and Fauna Guarantee Act 1988*, and *National Parks Act 1975* Research Permit 10007806; and
- Scientific Procedures Fieldwork Licence 20097.

2.2 Vegetation

Field work was carried out in the last week of October 2017 and vegetation monitoring was conducted at the following sites in the Anglesea Swamp: AS1_2014, AS2, AS3, AS4, ASP7_2014 and, AGP2_2014 and the following sites in the Anglesea Estuary: LAR1, LAR2, LAR3, and LAR4.

2.2.1 Floristic composition

At each of the sites, plant species plant species and Ecological Vegetation Classes (EVCs) following the Department of Environment Land Water and Planning (DELWP) benchmarks (DELWP 2018a) were recorded in sequential 1m² quadrats located along established 100m transects. The start and end of all transects are marked by steel pickets starting at zero metres. The quadrats are located on the left every second metre along the left hand side of the transect looking from start to end with the first quadrat placed at 1-2m, the second quadrat placed at 3-4m and so on to 99-100m.

There are a 50 quadrats along each transect in the swamp and 15 quadrats along LAR2, LAR3 and LAR4 transects and 7 quadrats along the transect at LAR1 in the estuary.

Field staff walk the right hand side of the transect to avoid trampling the quadrats on the left hand side.

Plant species were placed into respective Functional Groups (FGs) (see Table 1). The FGs and composition of EVCs were analysed to assess hydroecology (2.2.2) and structure (2.2.3).

2.2.2 Hydroecology

The FGs and EVCs were used to assess the degree of groundwater dependent vegetation across the swamp and estuary and the sensitivity of sites to groundwater drawdown.

Plant Functional Groups (Table 1) are based on the hydroecology (known or likely water requirements) of plant species, modified from Cassanova (2011), Doeg et.al. (2012) in Ecology Australia (2013b).

Functional Group data is presented in two forms in Figure 2, Figure 4, Figure 6, Figure 8, Figure 10 and Figure 12:

- Frequency and FG of the three most dominant species along the transect; and
- Frequency of each broad FG along the transect.

2.2.3 Structural attributes

Vegetation structure was documented through the recorded EVCs, dominant plant species and photo points. Photo points are located at 0m, 25m, 50m, and 75 m along each transect in the swamp and at the start of each transect in the estuary. Photos were taken looking toward the end of the transect.

2.2.4 Other attributes

Other transect attributes recorded were water depth (in the swamp only) and percentage cover of bare ground, rounded to the nearest 5%.

Water depth is a snap shot in time (one day of the year) and will vary considerably over time depending on rainfall. The presence of water is clearly a driver of wetland condition.

Water depth was not recorded in the estuary as water levels are managed and so remain fairly constant.

Bare ground provides space for recruitment. This can provide an indication of potential change at a site, for example – are the extant FGs recruiting, or are conditions favouring the recruitment of drier or wetter groups?

In 2016, large amounts of algal mat (consisting of filamentous algae) were observed in quadrats for the first time since the revised MAP monitoring commenced in 2014. The presence of an algal mat noted again in 2017 and was recorded in each quadrat.

2.2.5 Wetland boundaries

Wetland boundaries in the Anglesea Swamp were confirmed as far as practicable by mapping the interface between Swamp Scrub and Aquatic Sedgeland using aerials and ground-truthing. This mapping should detect significant boundary shifts in response to any longer term hydrological change.

2.2.6 Conservation status

Species of State and/or National status were determined by reference to DEPI's Advisory Lists (DEPI 2014) including listings under the Victorian *Flora and Fauna Guarantee Act 1988* (FFG Act) and the Federal *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

2.2.7 Nomenclature and taxonomy

Plant taxonomy and the use of common names in this report follow The Victorian Biodiversity Atlas (VBA) (DELWP 2018b).

Where an asterisk (*) precedes a plant name it is used to signify non-indigenous taxa, those species which have been introduced to Victoria or Australia. A hash (#) is used to denote Victorian plants that are not indigenous to the region or local area.



Figure 1 Anglesea Borefield revised ecological Monitoring and Assessment Program, 2017 survey sites

Table 1 Anglesea Borefield, revised ecological Monitoring and Assessment Program, Plant Functional Groups (modified from Cassanova (2011) and Doeg et.al. (2012))

Functional group code	Definition	Example species	Broad category
Tdr	<i>Terrestrial dry</i> . This species group does not require flooding and will persist in damper parts of the landscape because of localised high rainfall. Species in this group can invade or persist in riparian zones and the edges of wetlands, but are essentially terrestrial.	Messmate, Brown Stringybark, Prickly Moses, Silver Banksia	Dry
Tda	<i>Terrestrial damp</i> . These species germinate and establish on saturated or damp ground, but cannot tolerate flooding in the vegetative state. They require the soil profile to remain damp for at least several months.	Swamp Gum, Variable Sword-sedge, Manuka , Slender Bog-sedge	
ATI	<i>Amphibious fluctuation tolerator - low-growing</i> . This species group can germinate either on saturated soil or under water and grow submerged, as long as they are exposed to air by the time they start to flower and set seed. They require or tolerate shallow flooding for c. 3 months.	Austral Brookline, Swamp Club-sedge, Spotted Knotweed	Amphibious
ATe	<i>Amphibious fluctuation tolerator-emergent</i> . This species group consists of emergent monocots and dicots that survive in saturated soil or shallow water but require most of their photosynthetic parts to remain above the water (emergent). They tolerate fluctuations in the depth of water, as well as water presence. They need water or soil moisture to be present for c. 8-12 months of the year.	Tall Sedge, Red Fruit Saw-sedge, Pouched Coral-fern, Scrambling Coral-fern	
ATw	<i>Amphibious fluctuation tolerator- woody</i> . This species group consists of woody perennial species that may hold their fruits (and seeds) in the canopy and require water to be present in the root zone all year round, but will germinate in shallow water or on a drying substrate.	Woolly Tea-tree, Scented Paperbark	
ARp	<i>Amphibious fluctuation responder- plastic</i> . This species group occupies a similar zone to the ATI group, except that they have a morphological response to water level changes such as rapid shoot elongation or a change in leaf form. They can persist on damp and drying soil because of their morphological flexibility but can flower even if the site does not dry out. They occupy a slightly deeper/wet-for-longer site than the ATI group.	Creeping Cotula, Monkey Flower, River Buttercup	
Se	<i>Perennial-emergent</i> . This category refers to monocotyledonous species that require permanent water in the root zone, but remain emergent. They occur where water levels do not fluctuate or fluctuate with relatively little drawdown in the dry part of the year.	Cumbungi, Sea Rush, Southern Water-ribbons	Aquatic

2.3 Frogs

Frog surveys were undertaken twice, on 24 and 25 October 2017, and 13–15 November 2017, at the following twelve sites:

- AS1_2014, AS2, AS3, AS4, AS5, AS6, ASP7_2014 and AGP2_2014 in the Anglesea Swamp; and
- LAR1, LAR2, LAR3 and LAR4 in the Anglesea Estuary (Figure 1).

This includes the ten sites required by the MAP and two extra sites (AS5 and AS6), which are surveyed in the event that very low frog numbers are observed in the Anglesea Swamp.

2.3.1 Habitat assessment and water quality

Most habitat data was collected as part of vegetation assessments and monitoring. To supplement this information, the following variables were recorded in relation to frog habitat:

- Wetland permanence;
- Water quality parameters:
 - Temperature;
 - pH;
- Electrical Conductivity (EC);
- Dissolved Oxygen (DO);
- Turbidity; and
- A general habitat description, including levels of cover of fringing, emergent, submergent and floating vegetation where present.

Photos were also taken showing characteristic frog habitat.

2.3.2 Frog surveys

Two methods were used during surveys for frogs: aural surveys (diurnal and nocturnal) and nocturnal call playback surveys.

Diurnal and nocturnal aural surveys

Aural surveys were undertaken during the diurnal habitat assessments and at the beginning of each nocturnal survey for each site. They involved two zoologists listening for a period of approximately five minutes for the distinctive calls of male frogs. The species heard, and estimation of the number of frogs calling for each species, were recorded.

Nocturnal call playback

Following nocturnal aural surveys, call playback was used to elicit calling by male frogs that were not calling independently on site. This involved the broadcast of pre-recorded calls of each species via an MP3 player attached to a megaphone followed by a period of quiet listening. Frog calls broadcast during call playback, based on previous records included:

- Southern Brown Tree Frog *Litoria ewingii*;

- Southern Bullfrog *Limnodynastes dumerilii*;
- Spotted Marsh Frog *Limnodynastes tasmaniensis*;
- Striped Marsh Frog *Limnodynastes peronii*;
- Common Spadefoot Toad *Neobatrachus sudelli*; and
- Common Froglet *Crinia signifera*.

Call response data was used to estimate species richness and abundance within each site across the Anglesea Borefields and Estuary.

2.3.3 Conservation status

Species of State and/or National status were determined by reference to DELWP's Advisory Lists (DSE 2009, 2013) including listings under the Victorian FFG Act and the Federal EPBC Act.

2.3.4 Nomenclature and taxonomy

The scientific names, common names, and systematic orders of fauna species follow the Victorian Biodiversity Atlas (DELWP 2018b). In general, common names are used in the text.

2.4 Macroinvertebrate surveys

2.4.1 Macroinvertebrate sampling

Macroinvertebrate surveys were undertaken at three sites; W3, SC1 and BCT1 on 10–11 October 2017. Site BCT1 was relocated downstream as insufficient surface water was present at or within the vicinity of the coordinate provided. Based on photographs of BCT1 by GHD (2016), it was apparent that the site has previously been relocated to stream gauge SV3. Following consultation with Mark Dodgshun of Barwon Water, the survey was again undertaken at SV3, however for consistency it will be referred to as BCT1.

As per the methods outlined by GHD (2016), triplicate edge samples were collected at each site following the methods outlined in the Victorian Rapid Bioassessment (RBA) Methodology for Rivers and Streams (EPA 2003). A 0.25 mm mesh net with a 30 cm x 30 cm opening was used to collect each sample. Edge ('sweep') samples were collected from water bodies with little to no flow. The sampling objective was to subsample all types of habitats present, which can include overhanging vegetation, coarse woody debris, backwaters, bare edges, leaf packs and macrophytes. Each sample consisted of 10 m of habitat, which was not necessarily contiguous. The water and habitat was agitated to dislodge macroinvertebrates and suspend them within the water column. Additional invertebrates which were observed but not collected (e.g. fast moving) were noted on the sample label.

Samples were live-sorted ('picked') following the standard RBA procedures and preserved in jars using 70% ethanol. In summary, the procedures entail:

- Picking for 30 minutes from a white tray, aiming to collect 200 animals from as many different taxa as possible;
- If less than 200 animals are collected within 30 minutes then picking continues for an additional 10 minutes;

- If 200 animals are collected within 40 minutes and no new taxa are detected, then picking ceases; otherwise picking continues for an additional 10 minutes. This continues until a maximum of 60 minutes of picking has been completed; and
- Avoidance of favouring large and abundant taxa over smaller, more cryptic taxa, by picking a maximum of approximately 30 of each taxa, with the exception of animals which may superficially appear to be the same but typically require microscopic examination to identify the additional taxa (e.g. Chironomid subfamilies).

At each site, RBA field sampling and habitat assessment sheets were completed, including *in situ* water quality measurements using a calibrated U53 Horiba water quality meter.

2.4.2 Identification of macroinvertebrates

Macroinvertebrates were identified and enumerated using a stereo microscope using keys outlined in MDFRC (2013), which provides an update on those outlined in Hawking (2000). The majority of taxa were identified to family level with the following exceptions as per the RBA protocols (EPA 2003):

- Chironomidae are identified to sub-family;
- Oligochaeta and Acarina are not identified below these taxonomic levels;
- Adult and larval beetles are listed separately; and
- Taxa excluded from the recommended indices were discarded.

Additionally, specimens of the orders Ephemeroptera, Plecoptera, Trichoptera and Odonata were identified to genus level, as per GHD (2015—2017).

2.4.3 Analysis and interpretation of macroinvertebrate data

Macroinvertebrate data were analysed both as individual samples, and on a site basis using the combined data from three samples. The following indices were used to analyse macroinvertebrate data:

- Number of taxa – total number of taxa based on taxonomic resolution levels described in Section 2.4.2;
- Number of individuals – total number of individuals collected excluding those that were discarded (e.g. Collembolla, Staphlinidae beetles);
- Number of EPA key families – based on the number of taxa that have been identified as typical of waterways in this region (segment B3: Forests B) (EPA 2004);
- SIGNAL score – average SIGNAL score for taxa collected in each sample, using the scores adopted by EPA (2003). Table 2 provides an interpretation of the scores, which provide an indication of water quality;
- Number of EPT taxa – number of taxa from the orders of Ephemeroptera, Plecoptera and Trichoptera (EPT), which are considered more sensitive to pollution and disturbance and hence are considered an indicator of ecosystem health;
- Number of EPTO taxa – number of taxa from the orders of Ephemeroptera, Plecoptera, Trichoptera and Odonata (EPTO), this metric is used for waterways in ‘mediterranean climate’ regions, and aids in interpreting the health of lentic (still water) systems, where the numbers

of Plecoptera are diminished while Odonata, which are also relatively sensitive to pollutants and disturbance, are more abundant and diverse (Pinto et al. 2004)

Table 2 SIGNAL score classifications

SIGNAL score	Water quality
>7	Excellent
6-7	Clean water
5-6	Mild pollution
4-5	Moderate pollution
<4	Severe pollution

2.5 Fish surveys

Surveys targeting Southern Pygmy Perch *Nannoperca australis* were undertaken at two sites; SC1 and BCT1 on 10-11 October 2017. As with the macroinvertebrate surveys, site BCT1 was relocated downstream due to insufficient surface water at the point where the surveys were originally intended to be conducted (see Section 2.4).

Ten bait traps (mesh size of 2 mm and funnel entrances of 4 cm) with 4 inch yellow glow sticks were set in the afternoon and retrieved in the morning at both sites. This is a modification of the methods used by GHD (2015–2017), where it is believed that five bait traps were set each year, however it is not specified in the reports of the surveys conducted 2012–2016 (GHD 2013–2017). The number of traps was increased with the aim to increase the chances of collecting 30 Southern Pygmy Perch per site.

The first 30 Southern Pygmy Perch were measured (total length) to the nearest millimetre, and weighed to the nearest 0.1 gram. Subsequent Southern Pygmy Perch were counted and recorded. Additional taxa of interest detected in bait traps or observed at each site were recorded.

Instream habitat assessment was undertaken at all sites surveyed. The habitat assessment consisted of a fish habitat datasheet based on those used by the Arthur Rylah Institute. Habitat assessment included notes on existing sources of disturbance, notes and estimates of biological and physical attributes (e.g. wetted instream cover, riparian shading, aquatic vegetation, substrate composition, flow and depth) and *in situ* water quality measurement. An outline of some of these habitat descriptors is provided below:

- The percentage cover of various forms of instream habitat (based on the proportion of the wetted area that they covered at the time of assessment).
- The shading estimate as per the EPA Rapid Bioassessment method (EPA 2003). This is an estimate based on a plan view as it would appear with the sun directly overhead (i.e. midday).
- The flow status estimate is as per the USEPA fieldsheets that are incorporated into the latest iteration of the Victorian EPA Rapid Bioassessment fieldsheets (Version: September 2012). This is an estimate based on the proportion of the channel filled and/or substrate exposed.
- The disturbance rating estimate is based on identification of a number of disturbance sources including levels of bank erosion, riparian vegetation clearance, parallel or adjacent roads,

bridges/culverts/fords, rubbish, drain input, water extraction points, stock access, sedimentation, invasive exotic vegetation, barriers to fish passage, channelization and hydrological alterations; together with a severity rating (i.e. high, medium, low) applied to the disturbance sources that were identified at a given site.

Water quality measurements (dissolved oxygen (mg/L), pH, temperature (degrees Celcius), conductivity (mS/cm)) were made with a calibrated Horiba U-53 water quality meter.

3 Results

The vegetation and frog monitoring were conducted at the same sites (with two additional sites for frogs) and findings for each site are presented below followed by site summaries in section 3.2.3. The aquatic ecology monitoring was carried out at sites in different locations to the terrestrial monitoring sites and as such the site summaries are presented separately in Section 3.3.

3.1 Flora

Site summaries are provided in Figures 2, 4, 6, 8, 10 and 12.

3.1.1 Floristic composition

Thirty five native plant species were recorded across all sites in the Anglesea Swamp (Appendix 1), and 19 native indigenous plant species, three weeds and one non indigenous Victorian plant species were recorded in the Anglesea Estuary (Appendix 2).

The number of plant species at any one site ranged from 7- 17 in the swamp and 8-14 in the estuary (Table 2, Appendix 1 and 2).

The vegetation in the swamp remains healthy. No weeds were recorded in the swamp and there was little sign of disturbance.

The estuary vegetation is also relatively healthy, weeds did not make up the dominant species in any of the transects (Appendix 2, Figures 2, 4, 6, 8, 10 and 12). The estuary has walking paths which provide access to the estuary and surrounds. Faint tracks were observed through the vegetation adjacent to the transects possibly created by anglers and people walking their dogs, but native vegetation was on the whole growing well with good cover.

Table 3 Anglesea Borefield revised ecological Monitoring and Assessment Program, number of native plant species across monitoring sites and Functional Groups, 2017.

Transect/Site	Total number of native plant species	Number of plant species in a dry Functional Group (Tdr, Tda)	Number of plant species in an Amphibious Functional Group (ATI, Ate, ATw)	Number of plant species in an Aquatic Functional Group (Se)
Anglesea Swamp				
AS2	16	11	2	3
AS3	11	3	7	1
AS4	17	7	9	1
ASP7_2014	17	4	9	4
AS1_2014	12	4	5	3
AGP2_2014	7	1	4	2
Anglesea Estuary				

Transect/Site	Total number of native plant species	Number of plant species in a dry Functional Group (Tdr, Tda)	Number of plant species in an Amphibious Functional Group (ATI, Ate, ATw)	Number of plant species in an Aquatic Functional Group (Se)
LAR1	8	3	2	3
LAR2	10	4	4	2
LAR3	14	7	4	3
LAR4	8	2	4	2

3.1.2 Hydroecology

Plants from six of the seven FGs (Tdr, Tda, ATI, Ate, ATw, and Se) were recorded across the monitoring sites in the Anglesea Swamp, ARp was the only group not represented (Appendix 1). In the Anglesea Estuary, six of the seven FGs were also represented (Tdr, Tda, ATI, Ate, ARp, and Se) with ATw the only group not recorded.

3.1.3 Structural attributes

In the swamp, three EVCs were recorded: Swamp Scrub, representing an open to closed shrubland to 4m, Aquatic Sedgeland, characterised by a variably dense sedgeland to 1.3m and Heathy Woodland which has a eucalypt canopy over a shrubby understory. Overall, the wetland vegetation continues to be dominated by plants in the Amphibious and Aquatic FGs (Figures 2 to 7).

Two EVCs were recorded in the estuary: Swampy Riparian Woodland comprised of a low open eucalypt canopy to 8m with an understory of scattered woody shrubs and small herbs, and Estuarine Wetland comprised of a dense cover of reeds and rushes to 1 m, with scattered tussock grasses and small herbs.

3.1.4 Other attributes

Water was present at all six sites in the swamp. The average water depth ranged from 5-21cm, which is similar to 2016 (Figures 2, 4, 6, 8, 10 and 12).

Bare ground was recorded at five of the six sites in the Anglesea Swamp, and average cover ranged from 0-3% which is comparable to 2016 (Figures 2, 4, 6, 8, 10 and 12). In the Anglesea Estuary, bare ground was recorded at 2 of the four sites and average bare ground cover ranged from 1-3%, compared with 2015 when no bare ground was recorded (Figures 2, 4, 6, 8, 10 and 12).

Algal mat was present at five sites in the swamp and the number of quadrats occupied ranged from 1 (ASP7_2014) to 41 (AS1_2014) which is similar to the results recorded in 2016. No algal mat was recorded at any of the estuary sites.

3.1.5 Wetland boundaries

There were no material changes to the wetland boundaries represented by the interface(s) of Aquatic Sedgeland and Swamp Scrub (Figures 24 and 25).

3.2 Frogs

Of the eight monitoring sites at Anglesea Swamp, six had open standing water at the time of the first round of frog surveys on 24 and 25 October 2017. These sites remained wet at the time of the second round of frog surveys on 13–15 November 2017, although the area of standing water had generally contracted. In contrast, the Anglesea Swamp was largely dry during the 2014 and 2015 surveys, and most sites had little or no surface water present by the second survey in 2016.

3.2.1 Frog species richness and abundance

Anglesea Swamp

Frogs were recorded during both surveys at the Anglesea Swamp. All records were obtained at one site, AS2, where three species were recorded. All records during the first survey at AS2 comprised calling males of two species, the Common Froglet *Crinia signifera* and the Southern Bullfrog *Limnodynastes dumerilii*, rather than observed frogs (Table 4). One frog was recorded at AS2 during the second survey, comprising one Southern Brown Tree Frog *Litoria ewingii* observed perching on rushes (Table 4, Plate 1).

Anglesea Estuary

One Southern Bullfrog was heard at LAR4 during the first survey (Table 4), and Common Froglets and Southern Bullfrogs were heard calling in the distance from LAR2. No frogs were recorded at the Anglesea Estuary monitoring sites during the second survey.

Table 4 Anglesea Borefield revised ecological Monitoring and Assessment Program, frog species and estimated abundances, 2017.

Site	Common Froglet		Southern Brown Tree Frog		Southern Bullfrog		Species Richness
	1	2	1	2	1	2	
Anglesea Swamp							
AS2	10–20	0	0	1	<5	0	3
AS3	0	0	0	0	0	0	0
AS4	0	0	0	0	0	0	0
AS5	0	0	0	0	0	0	0
ASP7_2014	0	0	0	0	0	0	0
AS1_2014	0	0	0	0	0	0	0
AS6	0	0	0	0	0	0	0
AGP2_2014	0	0	0	0	0	0	0
Anglesea Estuary							
LAR1	0	0	0	0	0	0	0
LAR2	0	0	0	0	0	0	0
LAR3	0	0	0	0	0	0	0

Site	Common Froglet		Southern Brown Tree Frog		Southern Bullfrog		Species Richness
	1	2	1	2	1	2	
LAR4	0	0	0	0	1	0	1



Plate 1 Southern Brown Tree Frog *Litoria ewingii* observed at AS2, Anglesea Swamp, 14 November 2017.

3.2.2 Habitat assessment and water quality

Anglesea Swamp

The Anglesea Swamp monitoring sites are largely dominated by dense fringing vegetation of Scented Paperbark (*Melaleuca squarrosa*) and Manuka (*Leptospermum scoparium*), surrounding emergent aquatic vegetation including sedges such as Zig-zag Bog-sedge (*Schoenus brevifolius*), Twig-sedges (*Baumea* species), Saw-sedges (*Ghania* species) and Water Ribbons (*Cycnogeton alcockiae*). At sites supporting standing water, submergent and floating vegetation, usually filamentous algae, is sometimes observed. Some sites also include small patches of bare ground, and low cover of woody debris.

All monitoring sites are considered ephemeral except for AS3 (semi-permanent) and AS4 (semi-permanent to permanent). Six sites had sufficient standing water to allow water quality measurements to be taken. Both AS4 and AS5 had no standing water in either survey and water quality could not be measured. Most sites had a quite low pH (2.75–3.92) and electric conductivity ranged from 21–2,320

$\mu\text{S}/\text{cm}$, with all but one measurement above 1,000 $\mu\text{S}/\text{cm}$. Dissolved oxygen levels varied from 3.54–7.82 mg/L and water temperatures were relatively warm, ranging from 13.9–18.8 °C. Turbidity could not be measured at some sites given low water levels. Where measurements were possible, turbidity was relatively low (0–10 NTU).

Anglesea Estuary

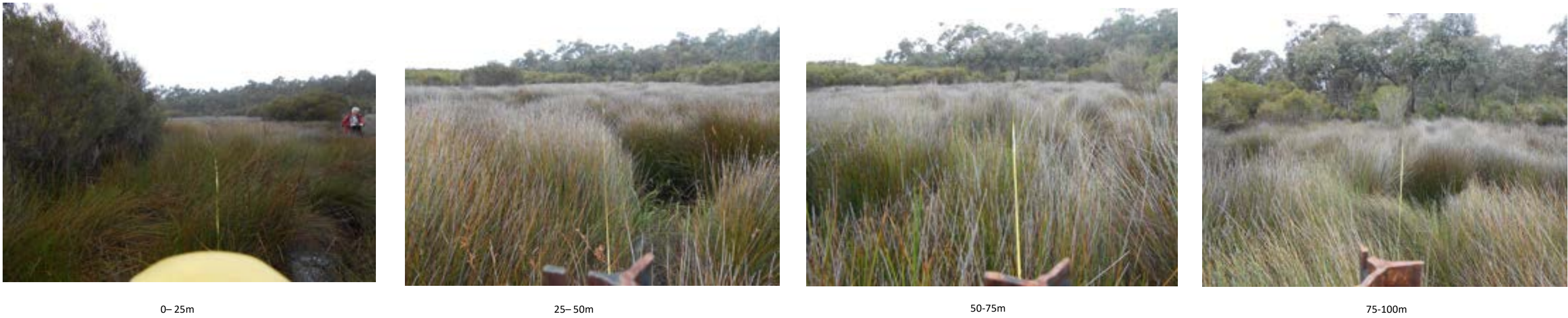
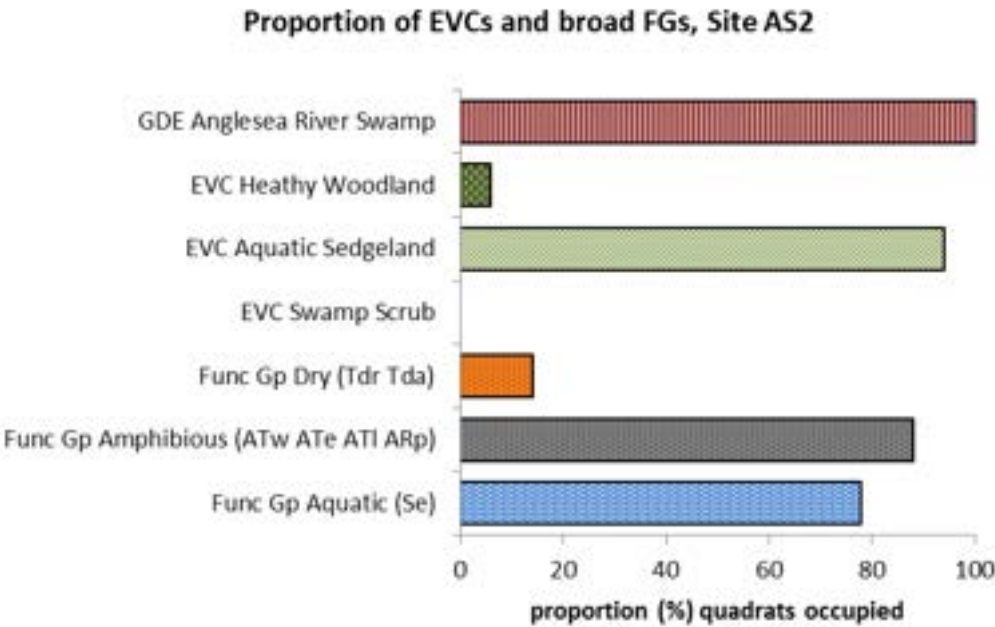
The Anglesea Estuary sites are dominated by fringing vegetation of grasses, sedges, rushes and herbs including Coast Tussock-grass, (*Poa poiformis* var. *poiformis*), Common Blown-grass (*Lachnagrostis filiformis*) (*Juncus kraussii* ssp. *australiensis*), Shiny Swamp-mat (*Selliera radicans*), Common Reed (*Phragmites australis*) and Narrow-leaf Cumbungi (*Typha domingensis*). There were scattered shrubs of Hop Goodenia (*Goodenia ovata*) and Manuka (*Leptospermum scoparium*) and stands of Swamp Gum (*Eucalyptus ovata* var. *ovata*) near the water's edge. Emergent vegetation, such as rushes, Common Reed, Cumbungi and Southern Water-ribbons, occurs relatively close to the banks; in deeper water, filamentous algae occurs as submergent vegetation.

All estuary monitoring sites are considered permanent, with stream widths ranging from 2–3 m to approximately 8 m. Water quality could be measured at all sites, and values were consistent between sites compared to measurements taken in the Anglesea Swamp. All sites had relatively low pH (3.82–3.89) and electric conductivity ranging from 2,710–3,250 $\mu\text{S}/\text{cm}$. Dissolved oxygen levels were relatively high (8.73–9.91 mg/L) and turbidity was consistently measured at 0 NTU. Water temperature varied from 17.7–18.6 °C

3.2.3 Flora and frog site summaries

These summaries include:

- transect photos at 25m intervals;
- the proportion of each EVC and each FG recorded at each site;
- the top three dominant plant species and their FG;
- other attributes including average bare ground cover, water depth algal mat;
- a habitat description;
- frog species occurrence and abundance;
- water quality data; and
- relevant comments.



Key:
GDE: Groundwater Dependent Ecosystem
EVC: Ecological Vegetation Class
FG: Functional Group

Dominant Plant Species		Broad FG	Quadrats occupied (% frequency)
<i>Schoenus brevifolius</i>	Zig-zag Bog-sedge	Amphibious	88
<i>Baumea tetragona</i>	Square Twig-sedge	Aquatic	50
<i>Cychnogeton alcockiae</i>	Southern Water-ribbons	Aquatic	44

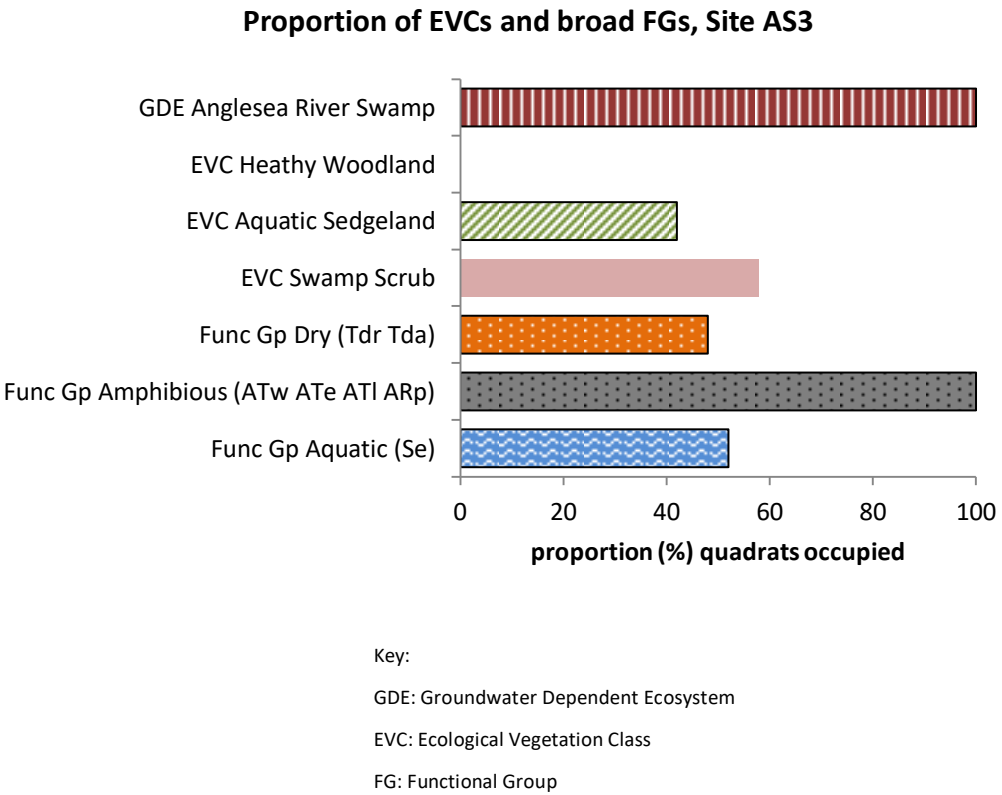
Other attributes		
Average % bare ground cover	1	(bare ground recorded in 3 quadrats)
Average water depth (cm)	14	Water recorded in 42 quadrats
Algal mat (quadrats occupied)	0	

Figure 2 Anglesea Borefield, revised ecological Monitoring and Assessment Program, Anglesea Swamp, Site AS2, vegetation summary data, 2017



AS2: General habitat description					
Ecological Vegetation Class (EVC)			Aquatic Sedgeland		
Wetland permanence			Ephemeral		
Moderate cover of emergent vegetation (50–70%), mostly comprising Zig-zag Bog-sedge, Square Twig-sedge and some Southern Water-ribbons, interspersed among pools of shallow (<10cm) open water. Filamentous algae occurs as both submergent (10–20%) and floating (<5%) vegetation. Aquatic vegetation is surrounded by dense (70–100%) cover of fringing vegetation, comprising Scented Paperbark and Manuka, and woodland at further distance from the swamp.					
AS2: Frog abundance and richness					
Southern Brown Tree Frog		Common Froglet		Southern Bullfrog	
Species Richness					
1		10–20		1–5	
3					
AS2: Water quality parameters					
pH	3.92	Turbidity	9 NTU	Water temperature	
18.6 °C					
EC	1060 µs/cm	Salinity	0.04%	Dissolved Oxygen	
5.7 mg/L					
Comments					
Common Froglets and Southern Bullfrogs heard during the first survey, in both diurnal and nocturnal surveys. One Southern Brown Tree Frog observed perching on rushes during the second survey. Southern Bullfrogs (1–5) heard calling in the distance, to the northwest, during the second survey.					

Figure 3 Anglesea Borefield Terrestrial revised ecological Monitoring and Assessment Program, Anglesea Swamp, Site AS2, Frog summary data, 2017



Dominant Plant Species		Broad FG	Quadrats occupied (% frequency)
<i>Schoenus brevifolius</i>	Zig-zag Bog-sedge	Amphibious	88
<i>Sprengalia incarnata</i>	Pink Swamp-heath	Amphibious	66
<i>Melaleuca squarrosa</i>	Scented Paperbark	Amphibious	62

Other attributes		
Average % bare ground cover	0	(bare ground recorded in 0 quadrats)
Average water depth (cm)	5	Water recorded in 30 quadrats
Algal mat (quadrats occupied)	0	

Figure 4 Anglesea Borefield, revised ecological Monitoring and Assessment Program, Anglesea Swamp, Site AS3, vegetation summary data, 2017



AS3: General habitat description							
Ecological Vegetation Class (EVC)		Swamp Scrub					
Wetland permanence		Semi-permanent					
Wet swamp with shallow standing water (10–15 cm) and dense emergent cover (70–100%) of Zig-zag Bog-sedge surrounded by thick fringing vegetation (70–100%) dominated by Scented Paperbark, Pink Swamp-heath and Pouched Coral-fern. No floating or submergent vegetation was observed.							
AS3: Frog abundance and richness							
Southern Brown Tree Frog		Common Froglet		Southern Bullfrog		Species Richness	
0		0		0		0	
AS3: Water quality parameters							
pH	3.62	Turbidity	0 NTU	Water temperature		13.9 °C	
EC	1120 µs/cm	Salinity	0.03 %	Dissolved Oxygen		5.9 mg/L	
Comments							
Swamp contained standing water during both surveys. No frogs seen or heard calling at the site during surveys, but Southern Bullfrogs (1–5) and Southern Brown Tree Frogs (6–10) heard calling in the distance.							

Figure 5 Anglesea Borefield revised ecological Monitoring and Assessment Program, Anglesea Swamp, Site AS3, Frog summary data, 2017



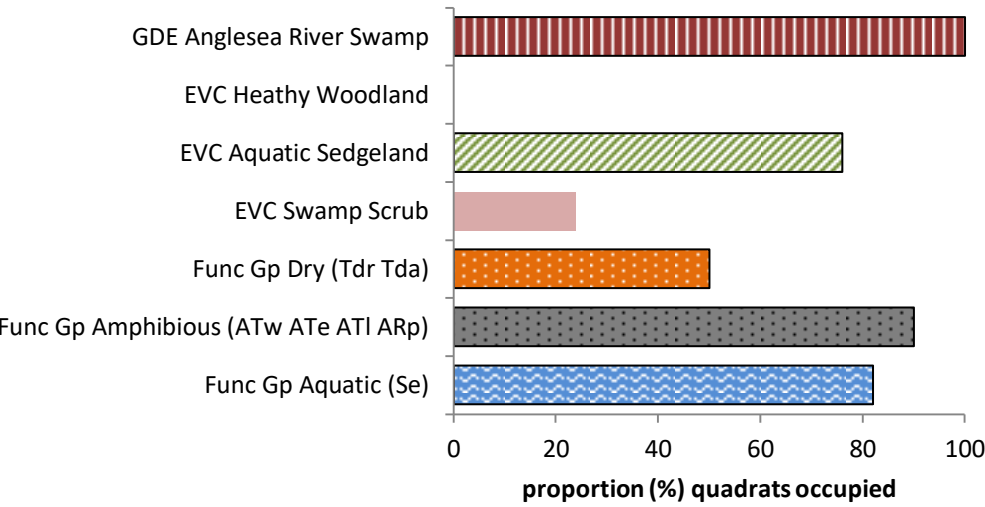
0– 25m

25– 50m

50-75m

75-100m

Proportion of EVCs and broad FGs, Site AS4



Key:
GDE: Groundwater Dependent Ecosystem
EVC: Ecological Vegetation Class
FG: Functional Group

Dominant Plant Species		Broad FG	Quadrats occupied (% frequency)
<i>Cynnogeton alcockiae</i>	Southern Water-ribbons	Aquatic	90
<i>Baumea arthropphylla</i>	Fine Twig-sedge	Aquatic	78
<i>Schoenus brevifolius</i>	Zig-zag Bog-sedge	Amphibious	54

Other attributes		
Average % bare ground cover	3	(bare ground recorded in 18 quadrats)
Average water depth (cm)	8	Water recorded in 37 quadrats
Algal mat (quadrats occupied)	2	

Figure 6 Anglesea Borefield, revised ecological Monitoring and Assessment Program, Anglesea Swamp, Site AS4, vegetation summary data, 2017



AS4: General habitat description					
Ecological Vegetation Class (EVC)			Aquatic Sedgeland		
Wetland permanence			Semi-permanent		
Frog site did not support standing water and was dry underfoot during both surveys. High cover of fringing vegetation (90%) includes Pouched Coral-fern, Manuka and Scented Paperbark. Low levels (5–10%) of bare ground and small amounts (<5%) of logs and fallen timber occurring at the site.					
AS4: Frog abundance and richness					
Southern Brown Tree Frog		Common Froglet		Southern Bullfrog	
0		0		0	
AS4: Water quality parameters					
pH	NA	Turbidity	NA	Water temperature	NA
EC	NA	Salinity	NA	Dissolved Oxygen	NA
Comments					
No frogs seen or heard during site visits.					

Figure 7 Anglesea Borefield revised ecological Monitoring and Assessment Program, Anglesea Swamp, Site AS4, Frog summary data, 2017



0–25m



25–50m

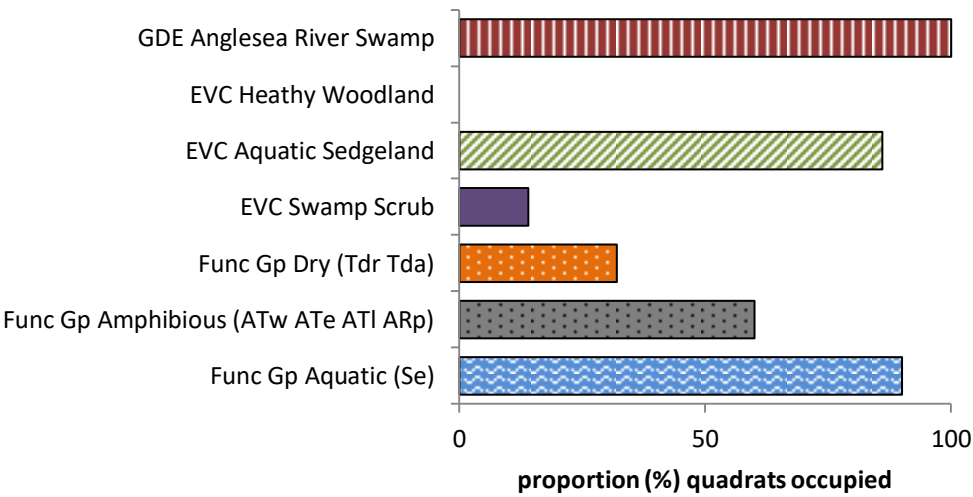


50–75m



75–100m

Proportion of EVCs and broad FGs, Site ASP7_2014



Key:
GDE: Groundwater Dependent Ecosystem
EVC: Ecological Vegetation Class
FG: Functional Group

Dominant Plant Species		Broad FG	Quadrats occupied (% frequency)
<i>Cycnogeton alcockiae</i>	Southern Water-ribbons	Aquatic	88
<i>Baumea arthropylla</i>	Fine Twig-sedge	Aquatic	76
<i>Schoenus brevifolius</i>	Zig-zag Bog-sedge	Amphibious	56

Other attributes		
Average % bare ground cover	<1	(bare ground recorded in 3 quadrats)
Average water depth (cm)	7	Water recorded in 40 quadrats
Algal mat (quadrats occupied)	1	

Figure 8 Anglesea Borefield, revised ecological Monitoring and Assessment Program, Anglesea Swamp, Site ASP7-2014, vegetation summary data, 2017



ASP7_2014: General habitat description					
Ecological Vegetation Class (EVC)			Aquatic Sedgeland		
Wetland permanence			Ephemeral		
Dense cover (90%) of emergent vegetation largely comprising dead and live Fine Twig-sedge and Zig-zag Bog-sedge with some Southern Water-ribbons. Small pools of open water, mostly shallow (c. 0.1 m) but with some pockets of deeper water. Dense fringing vegetation (90%) dominated by non-aquatic species such as Scented Paperbark.					
ASP7_2014: Frog abundance and richness					
Southern Brown Tree Frog		Common Froglet		Southern Bullfrog	
0		0		0	
				Species Richness	
				0	
ASP7_2014: Water quality parameters					
pH	3.31	Turbidity	10 NTU	Water temperature	14.8 °C
EC	21 µs/cm	Salinity	0.06%	Dissolved Oxygen	3.54 mg/L
Comments					
No frogs seen or heard during surveys.					

Figure 9 Anglesea Borefield revised ecological Monitoring and Assessment Program, Anglesea Swamp, Site ASP7_2014, Frog summary data, 2017



0– 25m



25– 50m

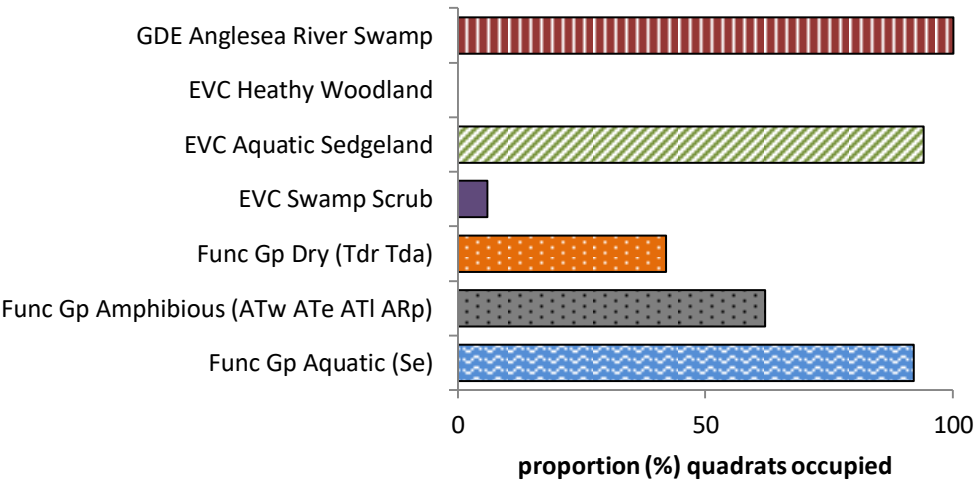


50-75m



75-100m

Proportion of EVCs and broad FGs, Site AS1_2014



Key:
GDE: Groundwater Dependent Ecosystem
EVC: Ecological Vegetation Class
FG: Functional Group

Dominant Plant Species		Broad FG	Quadrats occupied (% frequency)
<i>Cycnogeton alcockiae</i>	Southern Water-ribbons	Aquatic	90
<i>Baumea arthropphylla</i>	Fine Twig-sedge	Aquatic	54
<i>Schoenus brevifolius</i>	Zig-zag Bog-sedge	Amphibious	44

Other attributes		
Average % bare ground cover	1	(bare ground recorded in 4 quadrats)
Average water depth (cm)	14	Water recorded in 45 quadrats
Algal mat (quadrats occupied)	41	

Figure 10 Anglesea Borefield, revised ecological Monitoring and Assessment Program, Anglesea Swamp, Site ASP7-2014, vegetation summary data, 2017



AS1_2014: General habitat description					
Ecological Vegetation Class (EVC)		Aquatic Sedgeland			
Wetland permanence		Ephemeral			
A shallow (10–15 cm), open swamp, interspersed with moderate cover (20–50%) of emergent vegetation, comprising Fine Twig-sedge, Zig-zag Bog-sedge, Southern Water-ribbons and occasional Scented Paperbark. The majority of open water supports high cover (70–100%) of floating filamentous algae. Filamentous algae also observed as submergent vegetation at low levels (20–50%). Dense cover of fringing vegetation (70–100%) surrounds the swamp, including Scented Paperbark and Prickly Tea-tree. Low levels (<5%) of bare ground and cover of woody debris also occur on the edges of the swamp.					
AS1_2014: Frog abundance and richness					
Southern Brown Tree Frog	Common Froglet	Southern Bullfrog	Species Richness		
0	0	0	0		
AS1_2014: Water quality parameters					
pH	2.75	Turbidity	NA	Water temperature	18.8 °C
EC	2320 µs/cm	Salinity	0.11 %	Dissolved Oxygen	4.65 mg/L
Comments					
No frogs seen or heard during the surveys.					

Figure 11 Anglesea Borefield revised ecological Ecology Monitoring and Assessment Program, Anglesea Swamp, Site AS1_2014, Frog summary data, 2017



0– 25m



25– 50m

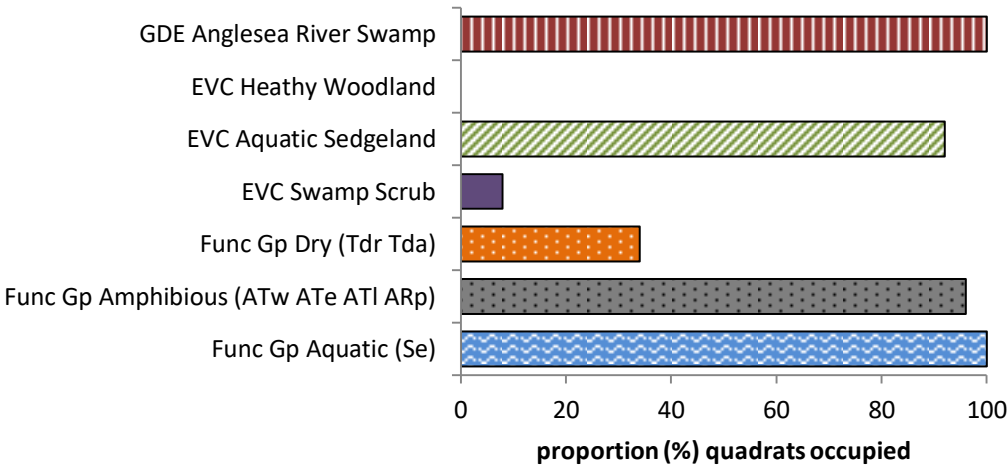


50-75m



75-100m

Proportion of EVCs and broad FGs, Site AGP2_2014



Key:
GDE: Groundwater Dependent Ecosystem
EVC: Ecological Vegetation Class
FG: Functional Group

Dominant Plant Species		Broad FG	Quadrats occupied (% frequency)
<i>Cycnogeton alcockiae</i>	Fine Twig-sedge	Aquatic	92
<i>Juncus procerus</i>	Tall Rush	Amphibious	72
<i>Melaleuca squarrosa</i>	Scented Paperbark	Amphibious	50

Other attributes		
Average % bare ground cover	<1	(bare ground recorded in 2 quadrats)
Average water depth (cm)	22	Water present in 48 quadrats
Algal mat (quadrats occupied)	32	

Figure 12 Anglesea Borefield, revised ecological Monitoring and Assessment Program, Anglesea Swamp, Site AGP2_2014, vegetation summary data, 2017



AGP2_2014: General habitat description							
Ecological Vegetation Class (EVC)			Aquatic Sedgeland				
Wetland permanence			Ephemeral				
A deeper swamp (0.3 m) with high levels of emergent vegetation (70-100%) comprising thick tall cover of Tall Rush, Fine Twig-sedge, and interspersed with more open areas supporting dense patches of Southern Water-ribbons and moderate cover of floating algae (20–50%). High cover of fringing vegetation including dense stands of shrubs including Scented Paperbark. Low cover (<5%) of both logs and fallen timber, and artificial substrates (pipes) along the edges of the swamp.							
AGP2_2014: Frog abundance and richness							
Southern Brown Tree Frog		Common Froglet		Southern Bullfrog		Species Richness	
0		0		0		0	
AGP2_2014: Water quality parameters							
pH	2.9	Turbidity	NA	Water temperature		16.5 °C	
EC	1820 µs/cm	Salinity	0.08%	Dissolved Oxygen		7.82 mg/L	
Comments							
No frogs seen or heard on site during the surveys. Southern Bullfrogs heard calling in the distance during the second survey.							

Figure 13 Anglesea Borefield revised ecological Ecology Monitoring and Assessment Program, Anglesea Swamp, Site AGP2_2014, Frog summary data, 2017

Supplementary frog monitoring sites



AS5: General habitat description					
Ecological Vegetation Class (EVC)			Aquatic Sedgeland		
Wetland permanence			Ephemeral		
Swamp not supporting surface water at the time of survey but soft underfoot. Open areas support moderate cover of emergent vegetation (30–50%) including dense mats of bog-sedge, twig-sedge and some Southern Water-ribbons. High cover of fringing vegetation (90%) including Scented Paperbark and Pouched Coral-fern. Small amounts (5%) of fallen timber also occurring at the site.					
AS5: Frog abundance and richness					
Southern Brown Tree Frog		Common Froglet		Southern Bullfrog	Species Richness
0		0		0	0
AS5: Water quality parameters					
pH	NA	Turbidity	NA	Water temperature	NA
EC	NA	Salinity	NA	Dissolved Oxygen	NA
Comments					
No frogs seen or heard during the surveys.					

Figure 14 Anglesea Borefield revised ecological Monitoring and Assessment Program, Anglesea Swamp, Site AS5, Frog summary data, 2017

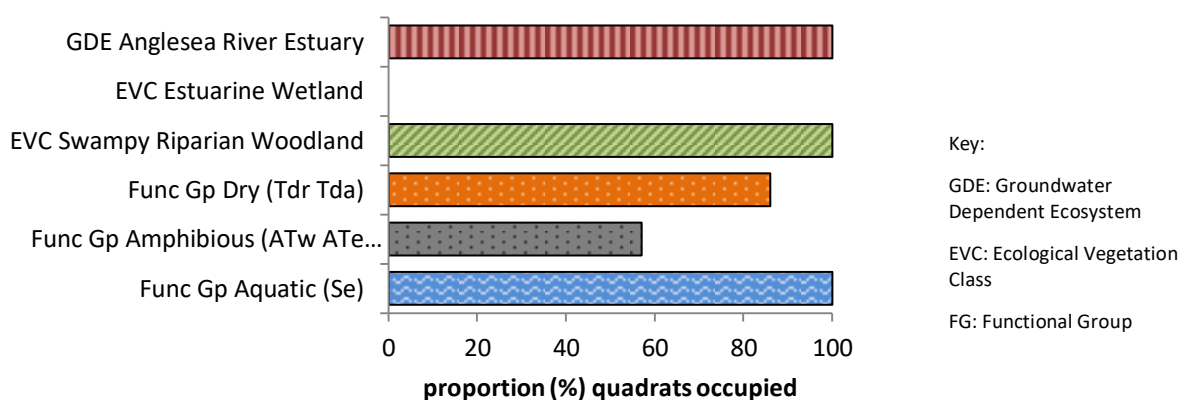


AS6: General habitat description							
Ecological Vegetation Class (EVC)			Aquatic Sedgeland				
Wetland permanence			Ephemeral				
Open swamp with high cover (70–100%) of emergent vegetation, largely dominated by bog-sedge and twig-sedge, of which the majority are dormant/dead, interspersed with small stands of Scented Paperbark and Manuka. Small areas of shallow (10–15 cm) open water were observed at the time of the survey. The swamp is surrounded by dense (70–100%) non-aquatic fringing vegetation.							
AS6: Frog abundance and richness							
Southern Brown Tree Frog		Common Froglet		Southern Bullfrog		Species Richness	
0		0		0		0	
AS6: Water quality parameters							
pH	2.82	Turbidity	0 NTU	Water temperature		16.4 °C	
EC	1660 µs/cm	Salinity	0.07%	Dissolved Oxygen		NA	
Comments							
No frogs seen or heard during the survey.							

Figure 15 Anglesea Borefield revised ecological Monitoring and Assessment Program, Anglesea Swamp, Site AS6, Frog summary data, 2017



Proportion of EVCs and broad FGs, Site LAR1



Dominant Plant Species		Broad FG	Quadrats occupied (% frequency)
<i>Cynogeton alcockiae</i>	Southern Water-ribbons	Aquatic	100
<i>Leptospermum scoparium</i> ,	Manuka	Dry	71
<i>Typha domingensis</i>	Narrow-leaf Cumbungi	Aquatic	57
<i>Goodenia ovata</i>	Hop Goodenia	Dry	57

Other attributes

Average % bare ground cover 0

Figure 16 Anglesea Borefield, revised ecological Monitoring and Assessment Program, Anglesea Estuary, Site LAR1, vegetation summary data, 2017

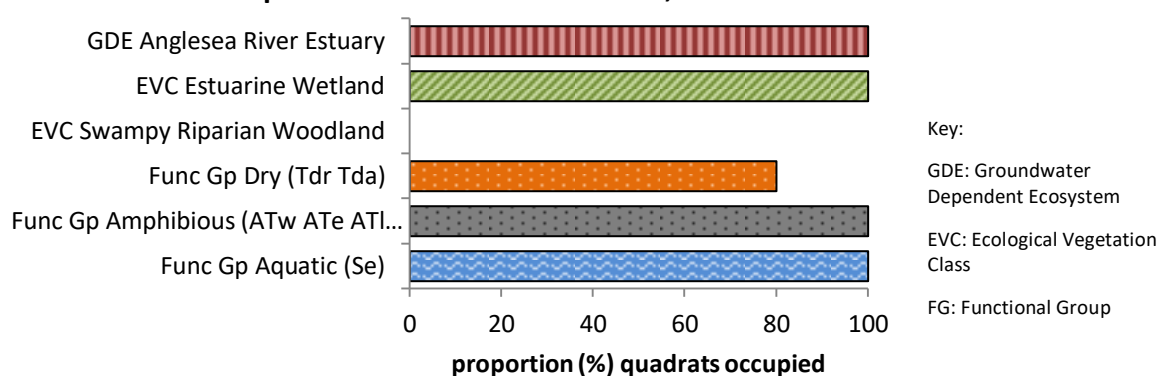


LAR1: General habitat description					
Ecological Vegetation Class (EVC)			Swampy Riparian Woodland		
Wetland permanence			Permanent		
Slow-flowing stream, 2–3 m in width. Dense (70–100%) fringing vegetation comprising Hop Goodenia, Scented Paperbark and Manuka. Low (10–20%) cover of emergent vegetation occurs within 1 m of the bank, including Common Reed, Narrow-leaf Cumbungi and Southern Water-ribbons. Small amounts of filamentous algae occurs as submergent vegetation (5–10%) covering rocks and concrete fragments, and floating vegetation (<5%).					
LAR1: Frog abundance and richness					
Southern Brown Tree Frog		Common Froglet		Southern Bullfrog	
0		0		0	
LAR1: Water quality parameters					
pH	3.83	Turbidity	0 NTU	Water temperature	
				17.7 °C	
EC	2710 µs/cm	Salinity	0.13%	Dissolved Oxygen	
				9.25 mg/L	
Comments					
No frogs seen or heard during the survey.					

Figure 17 Anglesea Borefield revised ecological Monitoring and Assessment Program, Anglesea Estuary, Site LAR1, Frog summary data, 2017



Proportion of EVCs and broad FGs, Site LAR2



Dominant Plant Species		Broad FG	Quadrats occupied (% frequency)
<i>Juncus kraussii</i> <i>ssp.australiensis</i>	Sea Rush	Aquatic	100
<i>Selliera radicans</i>	Shiny Swamp-mat	Amphibious	87
<i>Phragmites australis</i>	Common Reed	Amphibious	73
<i>Lachnagrostis filiformis</i>	Common Blown-grass	Dry	73

Other attributes		
Average % bare ground cover	0	

Figure 18 Anglesea Borefield, revised ecological Monitoring and Assessment Program, Anglesea Estuary, Site LAR2, vegetation summary data, 2017

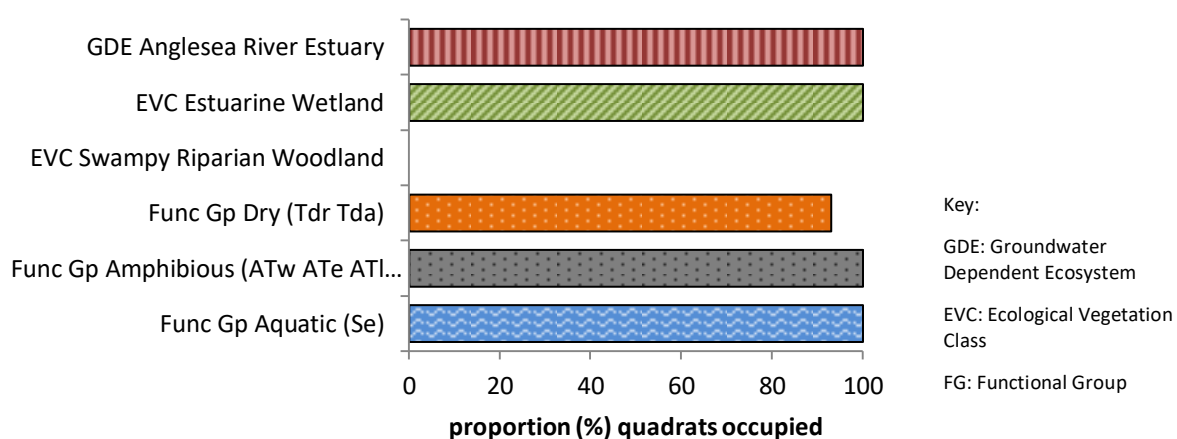


LAR2: General habitat description					
Ecological Vegetation Class (EVC)			Estuarine Wetland		
Wetland permanence			Permanent		
Slow-moving estuary stream, approximately 7 m wide, mostly comprising open water with moderate levels of filamentous algae occurring as submergent vegetation (50–70%). Low levels of emergent vegetation (<5%) occurs within 0.5 m of the bank comprising Common Reed, Sea Rush and Southern Water-ribbons. High levels (70–100%) of fringing vegetation occur on both banks. The west bank is fringed by a marsh of rushes, while the east bank supports planted vegetation followed by a boardwalk. Low levels (<5%) of bare ground and fallen timber occur at the site.					
LAR2: Frog abundance and richness					
Southern Brown Tree Frog		Common Froglet		Southern Bullfrog	
0		0		0	
LAR2: Water quality parameters					
pH	3.82	Turbidity	NA	Water temperature	
EC	2950 µs/cm	Salinity	0.14%	Dissolved Oxygen	
				18.3 °C	
				8.73 mg/L	
Comments					
No frogs seen or heard at the site. Approximately 10–20 Common Froglets and one Southern Bullfrog heard calling in the distance during the first survey.					

Figure 19 Anglesea Borefield revised ecological Monitoring and Assessment Program, Anglesea Estuary, Site LAR2, Frog summary data, 2017



Proportion of EVCs and broad FGs, Site LAR3



Dominant Plant Species		Broad FG	Quadrats occupied (% frequency)
<i>Juncus kraussii</i> <i>ssp.australiensis</i>	Sea Rush	Aquatic	100
<i>Cynnogeton alcockiae</i>	Southern Water-ribbons	Aquatic	100
<i>Poa Poiformis var.</i> <i>poiformis</i>	Coast Tussock-grass	Dry	73

Other attributes

Average % bare ground cover	0
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Figure 20 Anglesea Borefield, revised ecological Monitoring and Assessment Program, Anglesea Estuary, Site LAR3, vegetation summary data, 2017

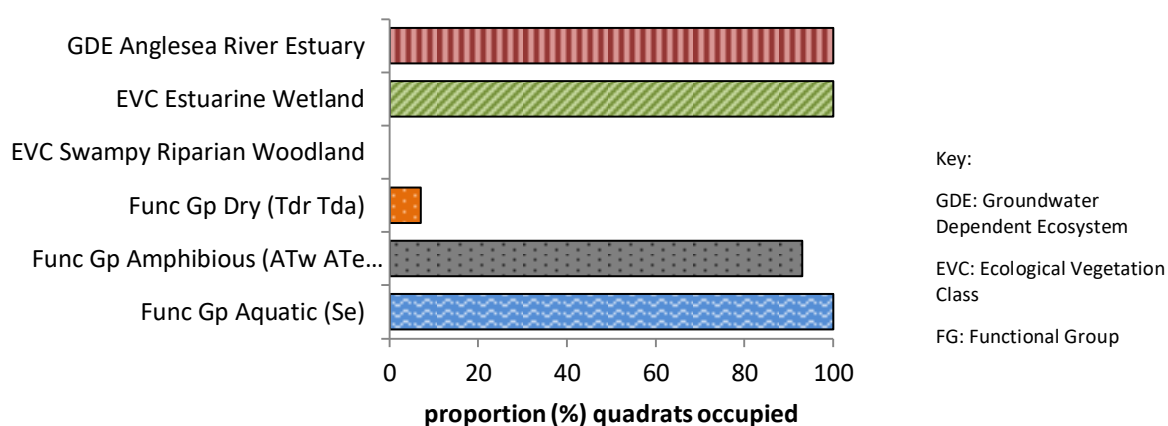


LAR3: General habitat description						
Ecological Vegetation Class (EVC)			Estuarine Wetland			
Wetland permanence			Permanent			
Slow-moving estuary stream, c. 6 m wide, with low (<5%) cover of Common Reed, rushes and Southern Water-ribbons as emergent vegetation near the banks. Moderate submergent cover (20–50%) of filamentous algae along the bottom of the stream. The site supports dense fringing vegetation (70–100%) comprising a marsh of Common Reeds to the east and Sea Rush and Shiny Swamp-mat to the west, with planted woodland vegetation at c. 4 m from the bank.						
LAR3: Frog abundance and richness						
Southern Brown Tree Frog		Common Froglet		Southern Bullfrog		Species Richness
0		0		0		0
LAR3: Water quality parameters						
pH	3.88	Turbidity	0 NTU	Water temperature		18.4 °C
EC	3110 µs/cm	Salinity	0.15%	Dissolved Oxygen		9.91 mg/L
Comments						
No frogs seen or heard during the surveys.						

Figure 21 Anglesea Borefield revised ecological Monitoring and Assessment Program, Anglesea Estuary, Site LAR3, Frog summary data, 2017



Proportion of EVCs and broad FGs, Site LAR4



Dominant Plant Species		Broad FG	Quadrats occupied (% frequency)
<i>Juncus kraussii</i> <i>ssp.australiensis</i>	Sea Rush	Aquatic	100
<i>Cynogeton alcockiae</i>	Southern Water-ribbons	Aquatic	100
<i>Selliera radicans</i>	Shiny Swamp-mat	Amphibious	93

Other attributes

Average % bare ground cover 0

Figure 22 Anglesea Borefield, revised ecological Monitoring and Assessment Program, Anglesea Estuary, Site LAR3, vegetation summary data, 2017



LAR4: General habitat description					
Ecological Vegetation Class (EVC)		Heathy Woodland			
Wetland permanence		Permanent			
Slow-moving 8-m wide estuary stream, comprising mostly open with minimal (5–10%) emergent vegetation dominated by Cumbungi and Southern Water-ribbons within 1 m of the bank. Submergent filamentous algae occurs at low levels (5–10%) within 2 m of the bank. The site is fringed by dense (70–100%) cover of Cumbungi and planted vegetation.					
LAR4: Frog abundance and richness					
Southern Brown Tree Frog	Common Froglet	Southern Bullfrog	Species Richness		
0	0	1	1		
LAR4: Water quality parameters					
pH	3.89	Turbidity	NA	Water temperature	18.6 °C
EC	3250 µs/cm	Salinity	0.16%	Dissolved Oxygen	9.09 mg/L
Comments					
One Southern Bullfrog heard at the site during the first survey but no frogs heard or seen during the second survey.					

Figure 23 Anglesea Borefield revised ecological Monitoring and Assessment Program, Anglesea Estuary, Site LAR4, Frog summary data, 2017



Figure 24 Anglesea Borefield revised ecological Monitoring Assessment Program, wetland boundaries, Anglesea Swamp, 2017

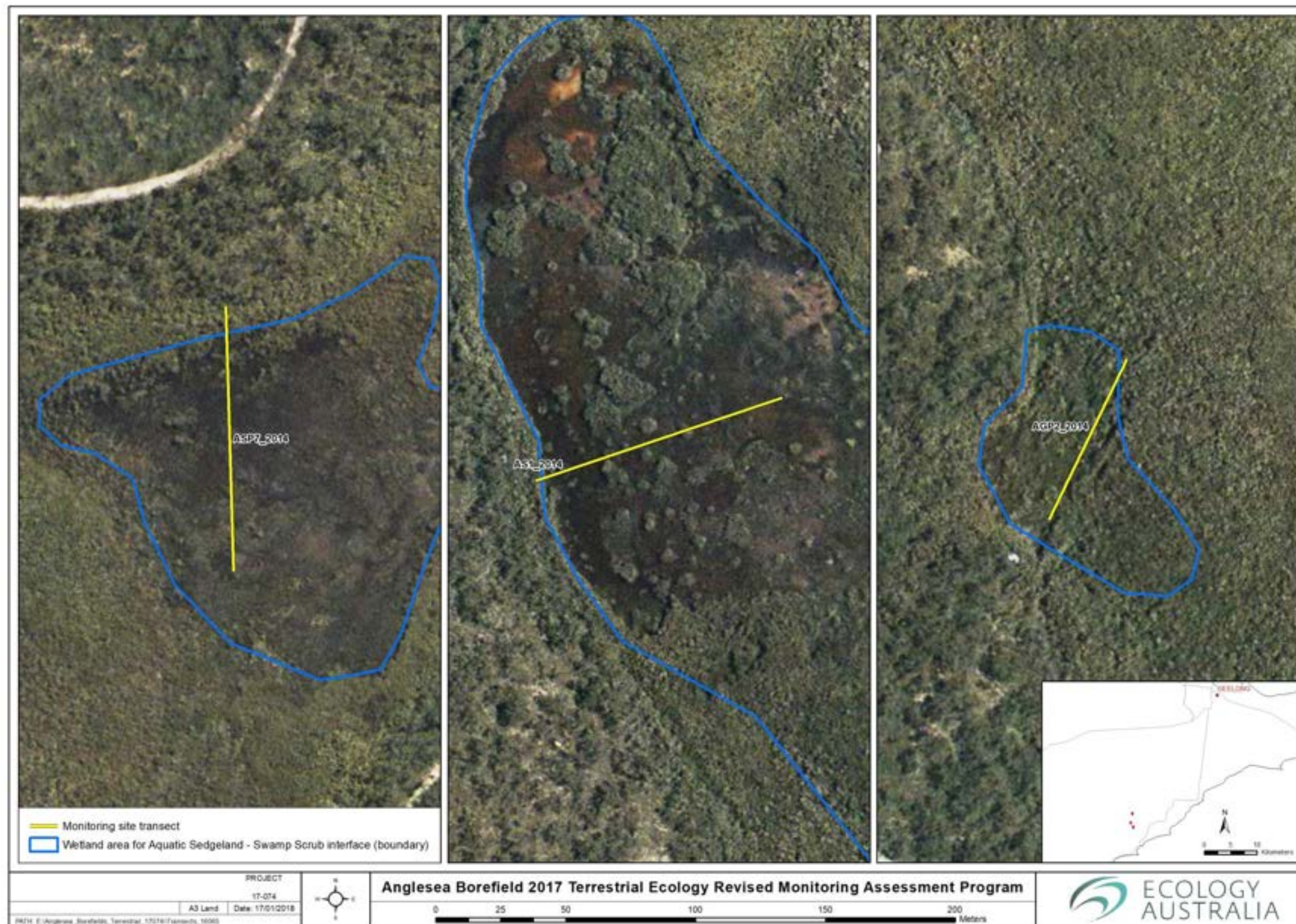


Figure 25 Anglesea Borefield revised ecological Monitoring Assessment Program, wetland boundaries, Anglesea Swamp, 2017

3.3 Aquatic monitoring

3.3.1 Macroinvertebrate results

The macroinvertebrate site results based on combined data from the three samples are provided in Table 5.

None of the nine samples collected contained sufficient macroinvertebrates to enable the sample to be picked in 30 minutes (each one had considerably less than 200 macroinvertebrates) and W3 was so depauperate that the combined data from three samples did not add up to 200 macroinvertebrates. Site W3 had the fewest taxa present, with only six detected across the three samples, and in one sample only two taxa were detected. This is substantially less than the SEPP objective (EPA 2004) of 23 taxa. Conversely, BCT1 and SC1 both attained SEPP objectives as combined samples.

None of the three sites attained SEPP objectives for EPA key families, and even the three sites combined were unable to attain the objectives, with W3 again performing considerably worse than BCT1 and SC1. All three sites attained SEPP objectives for SIGNAL scores when the three samples were combined, with SC1 attaining the highest score. No EPT or EPTO taxa were detected at W3, with BCT1 attaining the highest diversity for both EPT and EPTO.

Site W3 has not been surveyed since spring 2011 as it has regularly been dry at the time of survey, or an alternative wetland site has been surveyed. The results from spring 2017 are fairly consistent with those from 2011, however there were fewer taxa and fewer key families in 2017.

Site BCT1 has been regularly surveyed. The results from the past few years are fairly consistent, with some indices improving and others declining marginally. Between 2014 and 2017, the number of taxa, EPT and EPTO indices have improved, while key families and SIGNAL score have vacillated between higher and lower scores than in 2017.

Site SC1 has also been consistently surveyed. The overall number of taxa, number of EPA key families, and EPT taxa have increased substantially, and the SIGNAL score has also increased. The only metric where it has not improved is in the EPTO, as no Odonata were detected at SC1 in 2017.

The results of the individual macroinvertebrate samples will be further illustrated below by site (3.3.5)

Table 5 Macroinvertebrate survey indices: results by site (non-attainment of SEPP objectives indicated by shading)

Indices	W3	BCT1	SC1	Total	SEPP objective
# taxa	6	24	24	32	23
# individuals	158	216	231	605	N/A
EPA key families	5	15	17	19	21
SIGNAL score	5.33	5.78	5.9	5.83	5.3
EPT	0	6	5	7	N/A
EPTO	0	8	5	10	N/A

3.3.2 Southern Pygmy Perch results

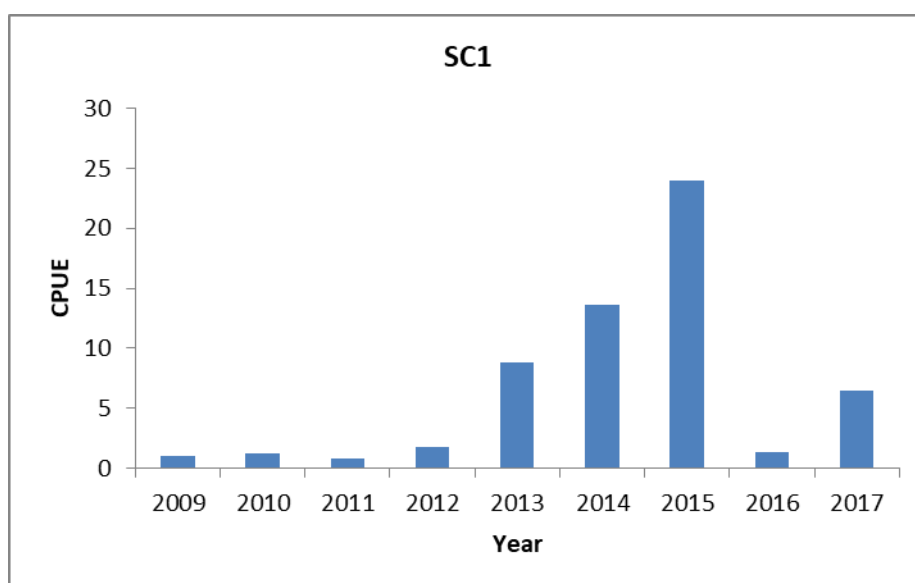
A total of 65 Southern Pygmy Perch were captured from Salt Creek (SC1), and 18 were captured from Breakfast Creek tributary (BCT1) (Figure 26 and Figure 27, Plate 2 and 3). These represent the fourth highest and third highest spring Catch Per Unit Effort (CPUE) respectively since 2010. CPUE was calculated based on the assumption that five bait traps were utilised each spring 2009–2016. It is unclear how many of the fish were detected via electrofishing versus bait traps in 2009 and 2010, or how many bait traps were used between 2012 and 2016 as it is not specified in the methods (GHD 2010–2017). The use of CPUE to compare results is imperfect, as there may be an interaction effect whereby utilising additional traps in a small area may reduce the capture rate per trap. Higher total abundances have been noted from BCT1 in the most recent three years of survey, while the abundance in SC1 appears to have been highly variable over the past three years, with 2017 showing promising signs after a potential population crash in 2016. Recruitment appears to have occurred annually at SC1, while it may have been opportunistic at BCT1 based on the length distributions of captured individuals.



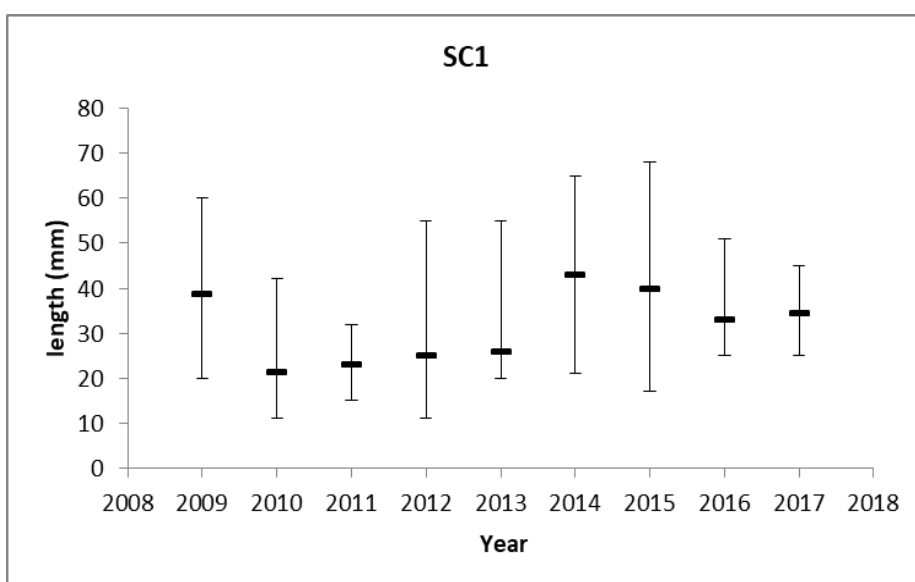
Plate 2 Male Southern Pygmy Perch from BCT1



Plate 3 Male and female Southern Pygmy Perch from SC1

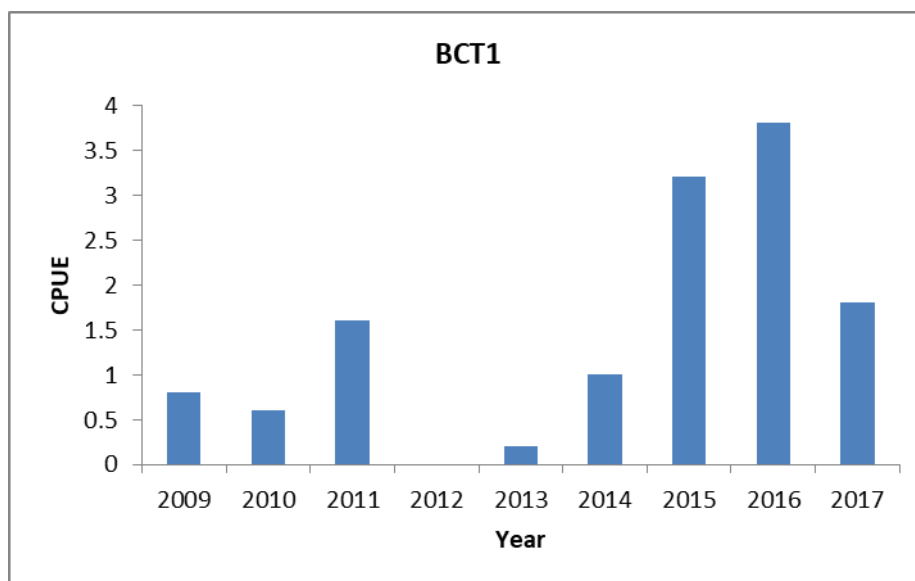


a) fish catch per unit effort at SC1.

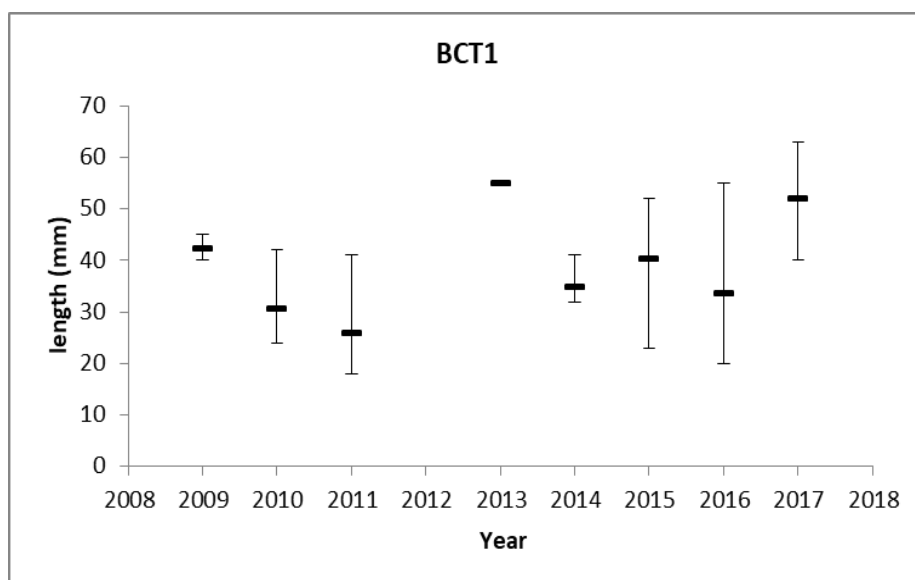


b) mean, minimum and maximum total length of measured Southern Pygmy Perch. $n = \text{CPUE} \times 5$ from Figure 27a), with the exception of 2017 where $n = \text{CPUE} \times 10$

Figure 26 Southern Pygmy Perch capture rates and length summary 2009-2017 at SC1



a) fish capture per unit effort at BCT1



b) mean, minimum and maximum total length of measured Southern Pygmy Perch. $n = \text{CPUE} \times 5$ from Figure 27a), with the exception of 2017 where $n = \text{CPUE} \times 10$

Figure 27 Southern Pygmy Perch capture rates and length summary 2009-2017 at BCT1

3.3.3 Water quality

Water quality results, whilst not attaining SEPP objectives for dissolved oxygen and pH, are fairly consistent with previous years (

Table 6).

Table 6 Water quality results (shading represents non-compliance with SEPP objectives)

	Temperature (°C)	Conductivity (μ S/cm)	Dissolved oxygen		pH
			mg/L	%Sat	
SEPP objective		<500		85-110	6.4-7.7
W3	10.97	312	4.52	40	2.77
BCT1	8.67	250	7.01	70	5.39
SC1	11.53	314	3.75	38	4.99

3.3.4 Non-target fauna and additional survey effort

An electrofishing spot check consisting of 243 seconds of power on time was undertaken on Breakfast Creek at the Breakfast Creek Road crossing, using a Smith Root LR24 backpack electrofisher. This was undertaken opportunistically in an effort to provide further information on the distributional extent of Southern Pygmy Perch and Otways Cray *Geocharax gracilis*.

Otways Cray was detected at two of the three surveys locations (BCT1 and SC1), and was also confirmed to occur at the Breakfast Creek Road crossing (Table 7, Plate 4, Plate 5). The crays were detected during the fish survey (bait traps), during the macroinvertebrate survey (dip nets), and by electrofishing. Otways Cray is listed as Endangered on the Victorian Advisory List of threatened invertebrates. There are no local records on the Victorian Biodiversity Atlas (DELWP 2017), however there is a published record from Salt Creek ~2007 (Schultz et al. 2007).

Table 7 Non-target fauna recorded during aquatic surveys

Non-target fauna	SC1	BCT1	Breakfast Creek at Breakfast Creek Road
Otways Cray	8 (dip net)	15 (dip net) 6 (bait trap)	5 (electrofishing)
Eastern Smooth Frog	Present (calling)		<5 (calling)
Eastern Smooth Frog (tadpole)	1 (dip net)		1 (electrofishing)



Plate 4 Otways Cray – Breakfast Creek



Plate 5 Otways Cray – BCT1

3.3.5 Aquatic monitoring results by site

Wetland 3 (W3)

At the time of survey, W3 was very shallow, contracted, and dominated by dense Scented Paperbark and Tea-tree. The substrate was predominantly clay/silt, with a gravel track running adjacent to the site and presenting a potential point source of pollutants and sediment. Filamentous algae was present in high abundance, and macrophytes and coarse particulate organic matter were present in moderate abundance. The majority of the site exhibited no obvious flow, with the exception of a small channel area adjacent to the roadside (i.e. downstream of the road culvert). W3 had very limited standing water; had there been any less the site would have been ruled out.

The macroinvertebrate results for the wetland site were poor for all indices other than SIGNAL (Table 8).

Table 8 Macroinvertebrate sample results at W3, displayed individually and combined for the site, showing SEPP objectives (shading indicates non-attainment of SEPP objectives)

	W3-1	W3-2	W3-3	W3	SEPP objective
# taxa	6	2	5	6	23
# individuals	58	30	70	158	-
Key families	5	1	4	5	21
SIGNAL	5.33	5.00	5.20	5.33	5.30
EPT	0	0	0	0	-
EPTO	0	0	0	0	-

Salt Creek (SC1)



Plate 6 Salt Creek at SC1, showing bait trap set for fish survey

Of the three sites, Salt Creek at SC1 had the largest area of surface water available for sampling, and appeared permanent, with depths exceeding 1.5 m. The substrate was silt/clay, and the flow velocity was dominated by lentic (still) habitats with approximately 10% glide within the surveyed reach. The main instream cover available for fish and macroinvertebrates, in decreasing order of prevalence, consisted of coarse particulate organic matter (e.g. leaves and other organic debris), overhanging terrestrial vegetation, aquatic vegetation, branches, overhanging bank and logs. There was some evidence of deer damage (pugging) around the site. The dominant aquatic vegetation types were *Juncus* sp, *Carex* sp and *Isolepis* sp.

The macroinvertebrate results for the Salt Creek site as a combined sample (i.e. combined data from three sampled) attained SEPP objectives for number of taxa, but did not as individual samples (

Table 9). Similarly to the other two sites, abundance and key families representation was poor. One of the three samples was particularly poor, with no EPT or EPTO taxa, and only 21 individuals collected. The SIGNAL scores indicated that the site suffers from mild pollution, but attained SEPP objectives.

Table 9 Macroinvertebrate sample results at SC1, displayed individually and combined for the site, showing SEPP objectives

	SC1-1	SC1-2	SC1-3	SC1	SEPP objective
# taxa	13	17	11	24	23
# individuals	94	116	21	158	-
Key families	10	14	8	17	21
SIGNAL	5.7	5.71	5.5	5.9	5.30
EPT	2	4	0	5	-
EPTO	2	4	0	5	-

Detected numbers of Southern Pygmy Perch and CPUE were higher in 2017 than 2016, but remain substantially lower than 2015. The length-frequency histogram suggests there are multiple age classes present at SC1, and that recruitment successfully occurred in the past 12 months. Southern Pygmy Perch reach maturity at approximately 30 mm (Robinson 2012), and five of the 18 fish detected were below this threshold (Figure 28).

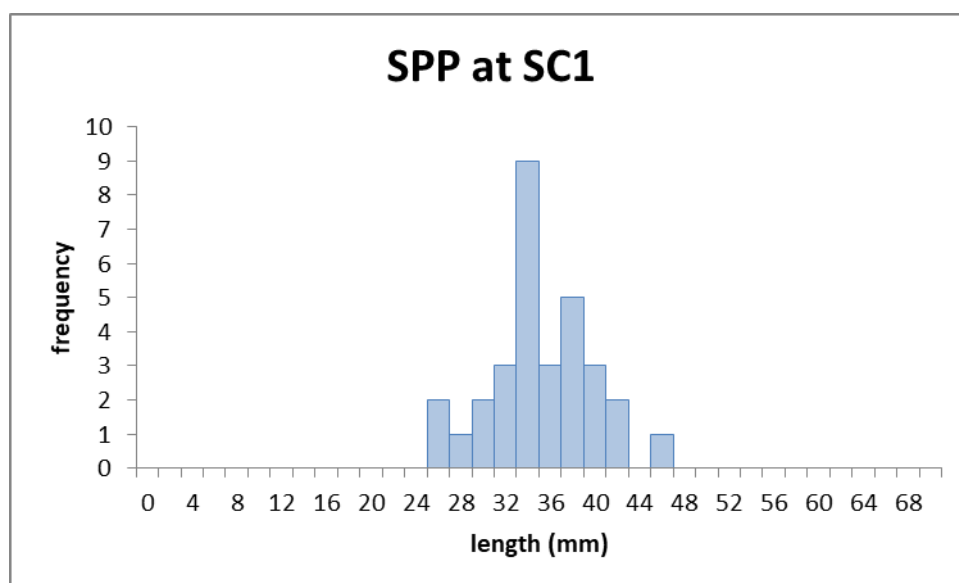


Figure 28 Length-frequency histogram of Southern Pygmy Perch at SC1. N=18

Breakfast Creek tributary (BCT1) at SV3

Plate 7 Breakfast Creek tributary (BCT1) at SV3, showing stream gauge

Breakfast Creek tributary at SV3 (relocated BCT1) consisted of a narrow, shallow stream, with a maximum width of 75 cm, maximum depth of 45 cm and an average depth of 15 cm. The substrate was silt/clay, and the flow velocity was dominated by lentic (still) habitats with less than 15% glide and 1% run within the surveyed reach. The main instream cover available for fish and macroinvertebrates, in decreasing order of prevalence, consisted of coarse particulate organic matter (e.g. leaves and other organic debris) (75%), overhanging terrestrial vegetation (50%), branches (10%), logs (<5%), aquatic vegetation (<1%), and overhanging bank (<1%). The dominant aquatic vegetation types were *Juncus* sp, *Carex* sp and *Blechnum* sp.

As with SC1, the macroinvertebrate results for the Breakfast Creek tributary site as a combined sample attained SEPP objectives for number of taxa, but did not as individual samples (

Table 10). Similarly to the other two sites, abundance was poor, and there was poor representation by key families. The results across the three samples were relatively consistent. The SIGNAL scores indicated that the site ranges between mild pollution and clean water, but attained SEPP objectives.

Table 10 Macroinvertebrate sample results at BCT1, displayed individually and combined for the site, showing SEPP objectives (shading indicates non-compliance with SEPP objectives)

	BCT1-1	BCT1-2	BCT1-3	BCT1	SEPP objective
# taxa	17	13	12	24	23
# individuals	82	33	101	231	-
Key families	12	9	10	15	21
SIGNAL	5.93	5.88	6.10	5.78	5.30
EPT	5	4	4	6	-
EPTO	5	6	5	8	-

Detected numbers of Southern Pygmy Perch were similar over the most recent three surveys, however CPUE was much lower in 2017. The length-frequency histogram suggests that recruitment failure may have occurred in the past 12 months, while length distributions from 2016 (GHD 2017) were indicative of successful recent recruitment at that time. Southern Pygmy Perch reach maturity at approximately 30 mm (Robinson 2012), and none of the fish detected in 2017 were below this threshold (Figure 29).

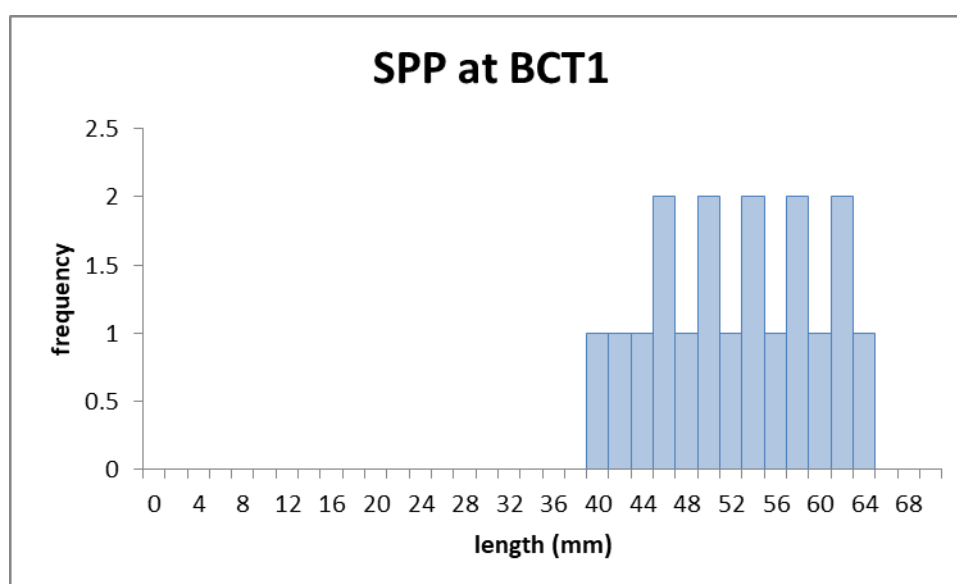


Figure 29 Length-frequency histogram of Southern Pygmy Perch at BCT1. n=31

4 Discussion

Vegetation

The terrestrial ecology monitoring of the Anglesea Swamp and Anglesea Estuary as in previous years, focused on plant functional groups and frogs and their distribution in the Anglesea Swamp and Estuary. The aquatic ecology component focussed on macroinvertebrate communities and Southern Pygmy Perch populations.

Mean annual rainfall was lower in 2017 (609mm) than in 2016 (714mm) and lower than the average mean annual rainfall (627mm) but still considerably greater more than in 2014 and 2015 (498 and 488mm respectively) based on data from the weather station at Aireys Inlet (BOM 2018). The greater rainfall may account for increased standing water being recorded at all six vegetation monitoring sites in 2016 and 2017 compared to prior years when very little standing water was recorded. Average water depth at the swamp monitoring sites ranged from 5–22 cm in both 2016 and 2017. The Anglesea Estuary is managed so water levels remain fairly constant, and water levels appeared similar to 2016.

The data suggests that EVCs remain unchanged from previous years in the Anglesea Estuary and Anglesea Swamp (Ecology Australia 2015 and 2016). There was little change observed in the plant FGs with amphibious and aquatic FGs continuing to be the dominant groups in the estuary in 2015 and 2017, and in the Swamp in 2016 and 2017 (Ecology Australia 2015 and 2016). Plant species numbers remained fairly consistent across all transects (Appendix 1).

It was noted for a second year that filamentous algal mats were present at some sites in the Anglesea Swamp. Algal mats were first recorded in 2016 and may be associated with reduced flows.

The Anglesea Estuary is prone to naturally occurring acid events under certain climatic conditions. The vegetation appears to be fairly resilient and persists through these events which can have more noticeable impacts on other biota such as fish.

Frogs

Despite the presence of surface water at six frog sites in the Anglesea Swamp during the surveys, frogs were recorded at fewer sites, and in generally lower abundances in 2017 compared with 2016. While frogs were heard calling from areas surrounding three sites, they were only recorded at one monitoring site (AS2), compared with records from four sites in 2016. Three frog species were recorded at AS2 (Common Froglet, Southern Brown Tree Frog and Southern Bullfrog), but numbers of Bullfrogs were much lower in the current survey (1–5) compared with numbers heard in 2016 (>20). More frogs were heard calling in the first survey in October compared with the second survey in November, when standing water levels were lower.

One Southern Bullfrog was recorded at a site (LAR4) in the Anglesea Estuary, compared with c. 10 Common Froglets and a Southern Bullfrog heard across three sites in 2015. A chorus of Common Froglets (10–20) were heard in the distance towards Anglesea township, but were not detected at the monitoring sites.

Consistent with previous reports (Ecology Australia 2014, 2015 and 2016) the results continue to suggest that water levels in the swamp are largely rainfall dependent and therefore variable. The vegetation remains resilient and appears to be adapted to this natural rainfall variability. Frog numbers were down

as they are dependent on adequate standing water for breeding and would require extended rainfall to build up more substantial numbers. They may also be sensitive to acid events in the estuary.

Depending on future responses of water regimes in the Anglesea Swamp to climate predictions not only may water levels in the Anglesea Swamp change but acid events affecting the estuary may alter. Eventually changes in plant FGs may be expected. Should conditions become drier and more acidic then it would be expected that frog numbers could decline, or certainly not increase above the levels observed.

Aquatic Ecology

Macroinvertebrate surveys provide an overview of the health of aquatic systems. The macroinvertebrate survey results were relatively consistent with previous years, with sites demonstrating slight improvements under some indices, and minor reductions in others. Site SC1 showed the most marked improvements compared with recent years, while W3 showed the most notable decline. W3 had a considerably lower pH level than the other two sites, which is likely to have an impact upon the biota present as a pH of 2.7 is likely to be inhospitable for many taxa. While low, this is a naturally acidic system and low pH is characteristic of the wetland sites. In addition, having rarely contained sufficient water for survey (it was last surveyed in 2011) the short hydroperiod of this wetland is likely to greatly influence the macroinvertebrate community composition and abundance. It should be noted that comparisons between these results and SEPP objectives (EPA 2004) are provided for consistency with previous reports however should be interpreted with caution. The SEPP objectives are based on the standard RBA methods. These surveys undertaken for this project were triplicate edge, single season samples from predominantly lentic habitats; standard RBA sampling entails edge and riffle samples collected in both autumn and spring from predominantly lotic habitats and never from wetlands. The use of multiple indices to analyse the status of the macroinvertebrate communities enhances the capacity to assess the state of the communities and hence the state of the aquatic systems, by mitigating for limitations in individual indices (Tiller and Metzeling 2002).

The Southern Pygmy Perch population in the Anglesea catchment was identified as genetically distinct from surrounding catchments, and at the time of genetic assessment, the historically abundant populations from the Anglesea River and surrounding wetlands were not detected (Cesar 2012). If further surveys were to yield similar results, then the populations present in Salt Creek and Breakfast Creek tributary may be an important source population for recolonisation lower in the catchment. During the 2017 spring surveys for Southern Pygmy Perch, the species was detected at both survey sites. Southern Pygmy Perch have been detected at both sites in every spring survey since 2010, with the exception of 2012 at BCT1. The population appears to have had successful recruitment in the past 12 months at SC1, where the abundance appears to have improved since 2016; whereas recruitment was not evident at BCT1 in 2017, despite abundance appearing stable. While the review of the MAP (GHD 2013b) suggested the BCT1 population was more stable, more recent surveys have detected more individuals and more consistent evidence of recruitment at SC1.

The most notable result from the aquatic ecological monitoring was the detection of the endangered Otways Cray. This species has been recorded twice in this region, in 2007 and 2017. Based on the abundance and size ranges encountered, it is likely that this species has maintained a population in the Breakfast Creek and Salt Creek catchments throughout this period. Consideration should be given to the inclusion of this species in the monitoring program in future years.

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Appendix 1 Anglesea Borefield, terrestrial ecology, Monitoring and Assessment Program, Anglesea Swamp, native plant species and Functional Groups

Key:

k = poorly known species classified under 'Advisory List of Rare or Threatened' (VROT) plants in Victoria' (DEPI 2014)

Status	Scientific name	Common name	Functional group	AS2	AS3	AS4	ASP7_2014	AS1_2014	AGP2_2014
	<i>Banksia marginata</i>	Silver Banksia	Tdr	✓		✓			
	<i>Baumea arthropophylla</i>	Fine Twig-sedge	Se			✓	✓	✓	✓
	<i>Baumea juncea</i>	Bare Twig-sedge	ATe				✓	✓	
	<i>Baumea tetragona</i>	Square Twig-sedge	Se	✓	✓	✓	✓		
	<i>Cassytha glabella</i>	Slender Dodder-laurel	Tdr		✓	✓	✓	✓	
	<i>Cassytha pubescens</i>	Downy Dodder-laurel	Tdr	✓					
k	<i>Chorizandra australis</i>	Southern Bristle-sedge	Se	✓			✓		
	<i>Comesperma ericinum</i>	Heath Milkwort	Tdr			✓			
	<i>Cryptostylis subulata</i>	Large Tongue-orchid	Se	✓					
	<i>Cycnogeton alcockiae</i>	Southern Water-ribbons	Se	✓		✓	✓	✓	✓
	<i>Dillwynia cinerascens</i>	Grey Parrot-pea	Tdr	✓					
	<i>Drosera binata</i>	Forked Sundew	Tda		✓	✓			
	<i>Eleocharis sphacelata</i>	Tall Spike-sedge	Se					✓	
	<i>Empodisma minus</i>	Spreading Rope-rush	ATe		✓	✓	✓	✓	✓
	<i>Epacris obtusifolia</i>	Blunt leaf-Heath	ATw		✓	✓	✓		
	<i>Eucalyptus willisii</i>	Shining Peppermint	Tdr	✓					
	<i>Ghania radula</i>	Thatch Saw-sedge	Tdr	✓					
	<i>Ghania sieberiana</i>	Red-fruit Saw-sedge	ATe			✓	✓		✓
	<i>Gleichenia dicarpa</i>	Pouched Coral-fern	ATe		✓	✓	✓	✓	
	<i>Isolepis inundata</i>	Swamp Club-sedge	ATI					✓	
	<i>Juncus procerus</i>	Tall Rush	ATe						✓
	<i>Lepidosperma longitudinale</i>	Pithy Sword-sedge	ATe			✓	✓		
	<i>Leptospermum continentale</i>	Prickly Tea-tree	Tdr			✓	✓	✓	
	<i>Leptospermum lanigerum</i>	Woolly Tea-tree	ATw			✓	✓		
	<i>Leptospermum scoparium</i>	Manuka	Tda	✓	✓	✓	✓	✓	✓
	<i>Melaleuca squarrosa</i>	Scented Paperbark	ATw	✓	✓	✓	✓	✓	✓
	<i>Opercularia varia</i>	Variable Stinkweed	Tdr	✓					
	<i>Platylobium obtusangulum</i>	Common Flat-pea	Tdr	✓					
	<i>Pteridium esculentum</i>	Bracken	Tdr	✓					
	<i>Pultenea gunnii</i>	Golden Bush-pea	Tdr			✓			
	<i>Pultenea spp.</i>	Bush-pea	Tdr			✓			
	<i>Rhytidosporum procumbens</i>	White Marianth	Tdr	✓					
	<i>Schoenus brevifolius</i>	Zig-zag Bog-sedge	ATe	✓	✓	✓	✓	✓	
	<i>Sprengalia incarnata</i>	Pink Swamp-heath	ATw		✓	✓			
	<i>Xyris operculata</i>	Tall Yellow-eye	ATe		✓		✓		

Appendix 2 Anglesea Borefield, terrestrial ecology, Monitoring and Assessment Program, Anglesea Estuary, native plant species and Functional Groups

Key:

= Victorian species not indigenous to the region, location or local area

* = Species not native to Victoria

Status	Scientific name	Common name	Functional group	LAR1	AS2	AS3	AS4
#	<i>Acacia longifolia</i> subsp. <i>sophorae</i>	Coast Wattle	NA	✓			
*	<i>Aster subulatus</i>	Aster-weed	NA		✓		
	<i>Cassytha melantha</i>	Coarse Dodder-laurel	Tdr				✓
	<i>Cycnogeton alcockiae</i>	Southern Water-ribbons	Se	✓	✓	✓	✓
	<i>Eucalyptus ovata</i> var. <i>ovata</i>	Swamp Gum	Tda	✓		✓	
	<i>Ficinia nodosa</i>	Knobby Club-sedge	Tdr			✓	
	<i>Frankenia pauciflora</i> var. <i>gunnii</i>	Southern Sea-heath	Tdr				✓
	<i>Gahnia sieberiana</i>	Red-fruit Saw-sedge	Ate	✓			
	<i>Goodenia ovata</i>	Hop Goodenia	Tdr	✓	✓	✓	✓
*	<i>Holcus lanatus</i>	Yorkshire Fog	NA			✓	
	<i>Isolepis inundata</i>	Swamp Club-sedge	ATi				✓
	<i>Juncus kraussii</i> ssp. <i>australiensis</i>	Sea Rush	Se	✓	✓	✓	✓
	<i>Lachnagrostis filiformis</i>	Common Blown-grass	Tdr		✓		
	<i>Leptinella longipes</i>	Coast Cotula	ARp		✓	✓	✓
	<i>Leptosperum scoparium</i>	Manuka	Tda	✓	✓	✓	
	<i>Lobelia anceps</i>	Angled Lobelia	ATe		✓	✓	✓
	<i>Phragmites australis</i>	Common Reed	ARp	✓	✓	✓	✓
*	<i>Plantago coronopus</i>	Buck's-horn Plantain	NA		✓		
	<i>Poa poiformis</i> var. <i>poiformis</i>	Coast Tussock-grass	Tdr		✓	✓	✓
	<i>Scenecio glomeratus</i>	Annual Fireweed	Tdr			✓	
	<i>Schoenus apogon</i>	Common Bog-sedge	Tda			✓	
	<i>Selliera radicans</i>	Shiny Swamp-mat	ARp		✓	✓	✓
	<i>Typha domingensis</i>	Narrow-leaf Cumbungi	Se	✓		✓	✓

Appendix 3 Macroinvertebrate survey results

Class/Order	Family/Subfamily	Genus	BCT1-1	BCT1-2	BCT1-3	SC1-1	SC1-2	SC1-3	W3-1	W3-2	W3-3	Grand Total
Acarina			2	4	7		4	3				20
Amphipoda	Paramelitidae				1		1					2
Amphipoda				2								2
Anaspidacea	Koonungidae					12	5					17
Coleoptera	Chrysomelidae (L)		1									1
Coleoptera	Dytiscidae (A)		1			10	8	1	3		3	26
Coleoptera	Hydrochidae (A)					2	2					4
Coleoptera	Hydrophilidae (A)		1		1		1	1	2		1	7
Coleoptera	Scirtidae (L)					2			32	18	43	95
Decapoda	Parastacidae	<i>Geocharax gracilis</i>	6	3	6		2	6				23
Diptera	Ceratopogoninae		1					1				2
Diptera	Chironomidae						1					1
Diptera	Chironominae		4	1	10	8	9	4	4		6	46
Diptera	Culicidae								16	12	17	45
Diptera	Orthoclaadiinae			2	1	18	4					25
Diptera	Psychodidae		1					1				2
Diptera	Simuliidae		1		13	10	34	1				59
Diptera	Tanypodinae					1	2		1			4
Ephemeroptera	Caenidae	<i>Tasmanocoenis</i>					2					2
Ephemeroptera	Leptophlebiidae	<i>Thraulophlebia</i>	1	1		12	10					24
Ephemeroptera	Leptophlebiidae	<i>Ulmerophlebia</i>			1							1
Ephemeroptera	Leptophlebiidae						4					4
Hemiptera	Veliidae		1	1		12	13	1				28
Isopoda	Janiridae	<i>Heterias</i>	1					1				2
Lepidoptera	Crambidae					1						1
Mecoptera	Nannochoristidae	<i>Nannochorista</i>	1					1				2
Odonata	Argiolestidae	<i>Austroargiolestes</i>		1								1
Odonata	Telephlebiidae	<i>Austroaeschna</i>		1	2							3
Odonata	Telephlebiidae/Brachytronidae		3	1								4
Oligochaeta				1		3	2					6
Plecoptera	Gripopterygidae	<i>Illiesoperla</i>	1	1	3	1						6
Plecoptera	Gripopterygidae		49		47	2	1					99
Trichoptera	Ecnomidae	<i>Dateronomina</i>	1		1							2
Trichoptera	Hydrobiosidae	<i>Taschorema</i> complex					1					1
Trichoptera	Leptoceridae	<i>Triplectides</i>	6	14	8		10					38
Grand Total			82	33	101	94	116	21	58	30	70	605